DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2008/77

Seismic Acquisition Report - LOMROG 2007

Acquisition of reflection and refraction seismic data during Oden's Lomonosov Ridge Off Greenland (LOMROG) cruise in 2007

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This report has been written in cooperation with the Department of Earth Sciences, University of Aarhus

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Summary

The primary objective of the Danish part of LOMROG was to collect bathymetric, seismic and gravimetric data in the Amundsen Basin and along the Lomonosov Ridge in order to acquire the necessary data according to Article 76 in UNCLOS. Despite severe ice conditions, useful bathymetric data covering the continental slope in various places, 135 km of seismic data in Amundsen Basin, 15 km on the Lomonosov Ridge and 165 km off North East Greenland were obtained. Gravity data were acquired along the ships track using gravimeter on board *Oden* and on the ice using a portable gravimeter.

During LOMROG valuable experience was gained both in relation to the use of the newly developed seismic equipment and how to operate under severe ice conditions in the area north of Greenland using two icebreakers.

The LOMROG cruise demonstrated that acquisition of bathymetric and seismic data of sufficient quality for substantiating a claim according to Article 76 of UNCLOS by a two ship operation is possible under the severe ice conditions that prevail in the area north of Greenland, and data acquisition would not have been feasible without the competent support from the Russian nuclear icebreaker *50 let Pobedy*.

1. Introduction

By Christian Marcussen, Geological Survey of Denmark and Greenland

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The Lomonosov Ridge off Greenland (LOMROG) project was designed to study the virtually unexplored area of the submarine Lomonosov Ridge ca. 350 km north of Greenland. The project idea was initiated by Martin Jakobsson and Christian Marcussen during the fourth International Conference on Arctic Margins (ICAM) in Halifax, Canada in 2003. The ice conditions north of Greenland are well known to be the toughest in the Arctic Ocean and the expedition strategy was to reach the southern Lomonosov Ridge by entering the ridge at about 87-88°N and work along its crest towards the south. No research from surface vessels had previously been carried out in this part of the Arctic Ocean. The interest in this ice-infested area stems from a range of scientific questions and the fact that Denmark needs to acquire geophysical data from this region in order to put forward a claim for an "extended continental shelf" under United Nations Convention on the Law of the Sea (UNCLOS) Article 76 (Marcussen et al. 2004). The LOMROG project's main scientific components were to study the

1. Paleoceanography
2. Glacial history
3. Oceanography
4. Tectonic evolution

in the Arctic Ocean.

In addition to these main components, a range of subprojects were added including studies of the role of sea ice in the transport of CO_2 from the atmosphere to the ocean, distribution of mercury in the atmosphere and ocean, and the gravity field in the Arctic Ocean (Jakobsson et al. 2008).

The Swedish Polar Research Secretariat (SPRS) was contacted with the expedition plans and a proposal including the scientific objectives was submitted to the Swedish Research Council (VR) and funded in 2005. Simultaneously, the LOMROG expedition was included in the budget for the Danish UNCLOS project. Furthermore, the cruise was incorporated as a component in the Arctic Palaeoclimate and its Extremes (APEX) research network program endorsed by the ICSU/WMO Joint Committee for the International Polar Year 2007-2008 (IPY) as a formal IPY activity.

SPRS initiated the logistical work in early 2006 of organizing LOMROG as a Swedish/Danish collaboration project with participating scientists also from Canada, Finland, and the USA. The Swedish icebreaker *Oden* was decided to be the main research platform and in order to acquire reflection seismic profiles in the expected severe ice conditions north of Greenland, it was suggested already at an early stage that one of the Russian nuclear icebreakers should be contracted for support. After negotiations with the Murmansk Shipping Company, the new Russian nuclear icebreaker *50 Let Pobedy* ("50 Years of Victory") was contracted by SPRS and financed by the Danish continental shelf project.

During the spring of 2007, *Oden* went through a major upgrade through the installation of a multibeam bathymetric sonar (Kongsberg EM120) and chirp subbottom profiler (Kongsberg SBP120). The sonar was financed by the Knut and Alice Wallenberg foundation and VR and the installation, which took place from April 17 to May 15, 2007 in the Landskrona dry-dock located in southern Sweden, was financed by the Swedish Maritime Administration (SMA). These instruments were key to the planned LOMROG operations. A successful Sea Acceptance Test (SAT) of the sonar installation was carried out between May 15 and 25, 2007 off the coast of north-western Norway. During this period, the handling of the seismic equipment, which had been designed to be towed in heavy ice conditions behind the *Oden*, was also tested.

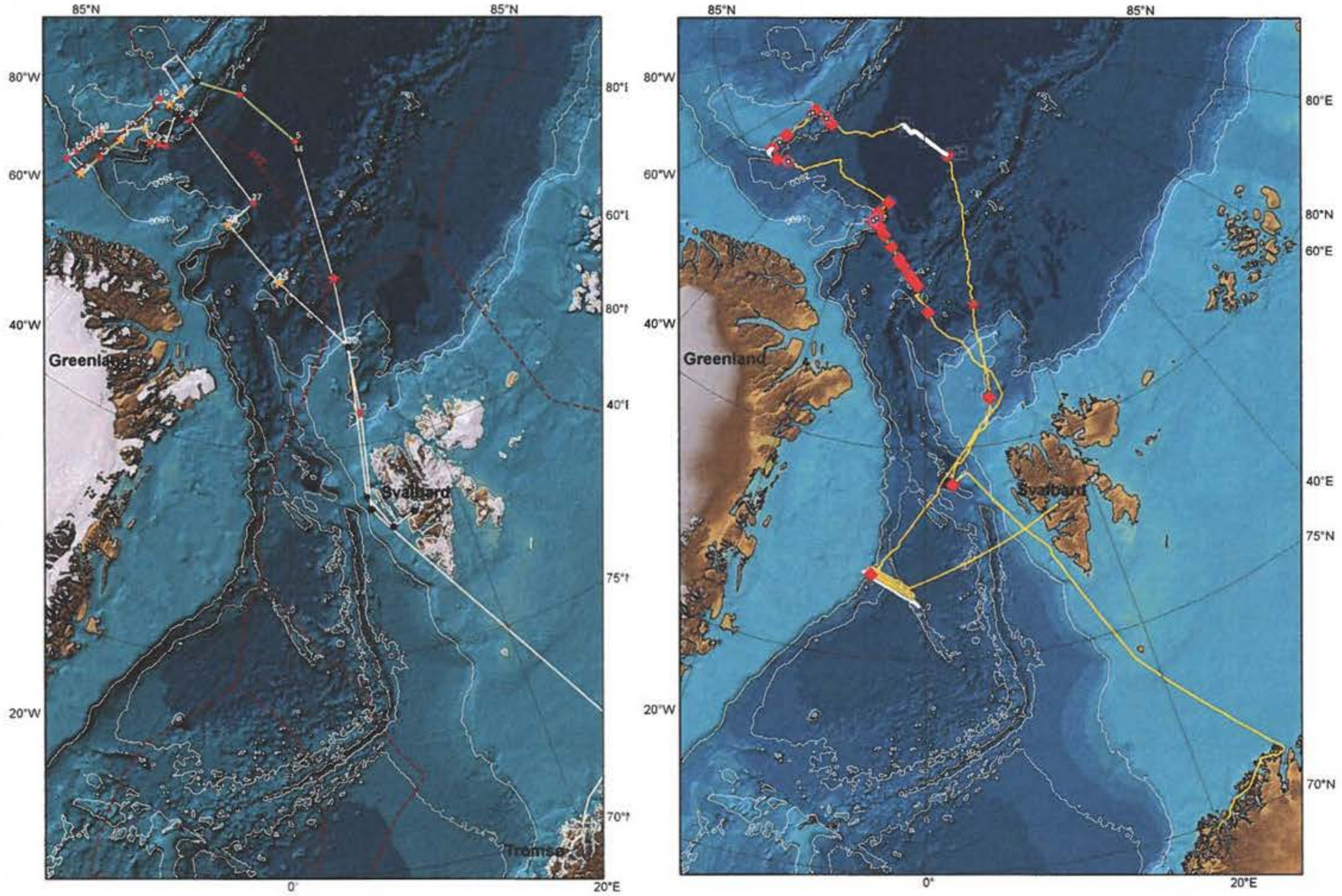

Figure A. *Initial LOMROG cruise plan (left). The red star shows the proposed rendezvous position between Swedish icebreaker Oden and Russian nuclear icebreaker 50 Let Pobedy ("50 Years of Victory"). Red dots indicate planned CTD stations, orange stars coring stations, and the green bold lines are planned reflection seismic profiles. The expedition started in Tromsø August 11, 2007. Dashed red lines indicate the exclusive economic zone (EEZ). The actual outcome of the expedition is shown to the right. The ship's track is shown as yellow line, white lines indicate position of reflection seismic lines.*

References:

Jakobsson, M., Marcussen, C. & LOMROG Scientific Party 2008: Lomonosov Ridge off

Greenland 2007 (LOMROG) – cruise report. Special Publication Geological Survey of Denmark and Greenland, Copenhagen, Denmark, 122 pp.

Marcussen, C., Christiansen, F.G., Dahl-Jensen, T., Heinesen, M., Lomholt, S., Møller, J.J. and Sørensen, K. 2004. Exploring for extended continental shelf claims off Greenland and the Faroe Islands – geological perspectives. Geological Survey of Denmark and Greenland Bulletin **4**, 61–64.

2. Reflection Seismic Equipment

By Thomas Vangkilde-Pedersen, Geological Survey of Denmark and Greenland, Holger Lykke-Andersen and Per Trinhammer, Department of Earth Sciences, University of Aarhus

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In the following a brief overview of the reflection seismic equipment used onboard *Oden* is given. Please refer to enclosure 1 (on CD-ROM) for further details.

2.1 Seismic Source

As seismic source a 605 cu.in. linear airgun cluster array was used consisting of two Sercel guns; one G-gun and one GI-gun. The guns were fired at 200 bar and the pressurized air was produced by 2 Hamworthy 70mm Series Air Compressors. A gun trigger unit, TGS-8, was triggered by NaviPac (see below) every 25 m and triggering the guns (Fig. 1). Communication to and from the airguns (trigger signal, depth transducer, near field hydrophone) was taking place through the umbilical cable also including hoses for the air supply. The umbilical cable was handled using a hydraulic winch. A wire winch was used for handling of the airgun cluster. Furthermore the wire winch was also used for deployment and recovery of the gravity and piston core sampling equipment.

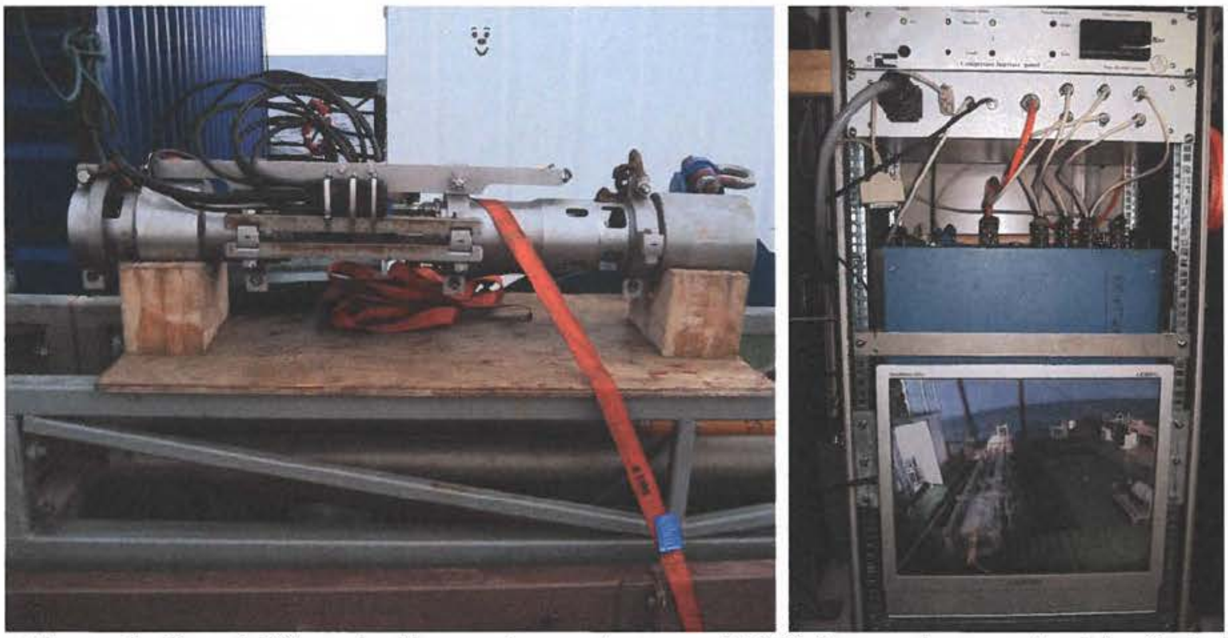

Figure 1. *Sercel 605 cu.in. linear airgun cluster and TGS-8 gun trigger unit with aft deck monitor screen.*

A hydrophone was placed at each G-gun to measure and synchronize (in the TGS-8 trigger unit) the mechanical firing delay of the shots. The two G-guns were fired simultaneously, while the I-gun (injector) was fired using a delay with the purpose of reducing the collapse of the air bubble and thereby the bubble pulse. The optimum delay is depending on the gun tow depth and the P/B ratio was measured to be highest at a delay of 65 msec. Later during the survey it turned out that there was actually no firing delay of the injector due to a software failure in the TGS-8 gun controller. Nevertheless the pulse-to-bubble (P/B) ratio was generally observed to be better than 30.

In addition, a depth transducer was mounted on the gun array in order to monitor the tow depth of the array. The transducer values were updated after each shot and monitored and recorded on the TGS-8 PC from where they were extracted as text documents.

2.2 Streamer

The streamer was a digital 48 channel Geometrics GeoEel streamer with one 50-m stretch section and six live sections with a total active length of 300 m (Fig. 2). There were eight Benthos GeoPoint hydrophones in each channel. Power supply to the streamer and all data communication from the streamer took place through the umbilical cable. In the front of each live section was a depth transducer and an A/D module; in the front of the stretch section was a repeater module for transmitting the signals through the lead-in cable of the streamer. A streamer power supply unit (SPSU) provided power to the A/D modules, trigger interface and ethernet connection to the streamer. A hydraulic winch was used for handling the streamer.

Figure 2. *Geometrics GeoEel streamer and the streamer power supply unit SPSU.*

2.3 Handling of Air Guns and Streamer under Severe Ice Conditions

The strategy the for handling of air guns and the streamer in the ice was based - to a large extent - on the experience gained by other workers on previous seismic cruises in the Arctic Ocean. The two prime concerns were to minimize the risk for ice-induced physical damage of the equipment towed in the water behind the icebreaker and to reduce the risk for having the streamer forced up towards the ice by the turbulent and forceful propeller wash.

It was found that the only reasonable way to achieve these goals would be to increase the tow depth to calm waters below the propeller wash since this depth was unknown, the tow system was constructed to allow for large flexibility in towing depth.

During data acquisition it was found that it was possible to keep the air guns and the streamer in approximately the same depth and that the streamer was unaffected by the propeller wash at a depth of approximately 20 m.

The choice of 20 m as tow depth has negative consequences for the data quality, which are related to the ghost effect . The amplitudes of certain frequency components of the seismic signal will be attenuated due to interference between the outgoing signal from the air guns and the signal reflected from the water-ice/ice-atmosphere boundaries 20 m above the air guns, and due to interference between the incoming signals to the receivers in the streamer and the reflected signals from the water-ice/ice-atmosphere boundaries 20 m above the streamer.

Theoretically, at 20 m depth the ghost phenomenon produces attenuation of signal amplitudes around the frequencies 37.5, 75 and 112.5 Hz (and higher frequencies with intervals of 37.5 Hz). Frequency bands applied in the preliminary processing of data onboard the icebreaker indicated that the reflections contain frequencies from lowest values at 10-20 Hz to highest values at 100 Hz. Thus, it may be concluded that the choice of 20 m as the tow depth most likely has a negative effect on the seismic signal, resulting in a reduction of the resolution in the seismic profiles.

2.4 Acquisition System

Data were recorded in SEG-D (8058 revision 1) on a PC running the seismic controller Geometrics GeoEel software CNT-2. The controller was connected to the SPSU via Ethernet and receiving the digitized signals from the streamer as well as auxiliary channels 1-4. On auxiliary channels 1 and 2 data from two sonobuoy radio receivers was recorded (see also sonobuoy report in section 7) and on auxiliary channel 3 the PPS pulse from the GPS. Auxiliary channel 4 was idle. Data were recorded simultaneously on LTO-2 tapes with a capacity of 200 GB and on a RAID 250 GB hard disk.

The navigation software NaviPac (see below) sends an event trigger every 25 m and a string to Com port 1 on the CNT-2 PC. The string contains time, event, position (x, y), depth, and is transferred to the SEG-D external header on tape and hard disk. The CNT-2 PC could not recognize this string if it was sent at the same time as the event trigger. It was therefore necessary to add a delay between the event trigger and the actual trigger signal send out from the gun PC (TGS-8). It turned out that a delay of 1100 ms in the gun PC was necessary to secure correspondence between event numbers and file numbers.

The seismic controller provided the following display facilities during survey (see also Fig. 3):

- A shot gather window where various display settings could be changed as appropriate.
- A real-time brute stack window where various processing and display parameters could be changed as necessary.
- A noise window showing noise values in µbar from all 48 channels as a "snapshot" calculated between shots.
- A trigger window showing the time interval between shots and the energy of a specified hydrophone (in this set-up channel 1).

- A streamer depth window displaying the depth from each depth transducer module.

Figure 3. *Seismic controller display facilities, shot gather window to the left and brute stack window to the right.*

During the survey the CNT-2 software generated a log file named Lomrog07_linenumber.0000 with the following format:

- First line is read from the serial input from the NaviPac software described below (not all numbers are readable in the log file, but all data are stored in the SEG-D header). The format of the string is: time HH:MM:SS (UTC), event no, X pos, Y pos (UPS, WGS 84, LC 605 gun array position), depth (from the ships data)<CR> <LF>.
- Second line is file no., exact CNT-2 trigger time, size in Kb and reel number.

Furthermore, data from the streamer depth transducers were stored in a text file and the real-time brute stack in an internal file-format. These files were named Lomrog07_linenumber.0000.depth and Lomrog07_linenumber.0000.gather1, respectively. When a line was finished the brute stack was converted to SEG-Y format and imported to the seismic interpretation software Kingdom Suite for printing on an Epson A1 printer.

2.5 Navigation and Positioning System

A separate Thales DG16 GPS was used for positioning of the reflection seismic equipment together with the navigation and data logging software NaviPac from EIVA A/S. The GPS has a built-in beacon and WAAS receivers for differential corrections. However,the survey area in the Arctic Ocean was outside the coverage area of both systems and the GPS was used without differential corrections. NaviPac received antenna coordinates from the GPS, water depth below transducer (8 m below sea level.) from the center beam of the ships Kongsberg EM120 multibeam echo sounder and gyro course from the ship's Furuno gyro. The NaviPac system provided the trigger signal for the TGS-8, and an event trigger and data string for the CNT-2 controller. Runlines (survey lines) were generated in the so called Helmsman's display part of NaviPac and the survey is controlled from this display (Fig. 4). The option of distributing runline data to a Helmsman's display on the bridge running in slave mode was not used.

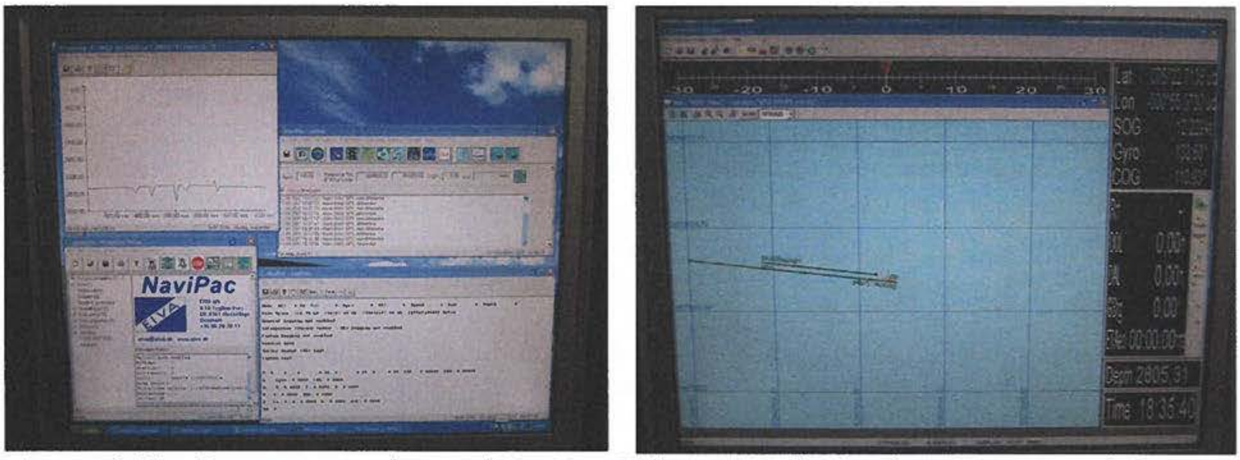

Figure 4. *NaviPac setup window and NaviPac Helmsman's display for survey control.*

2.6 Container and Equipment Setup on *Oden*

Several containers were used for the reflection seismic operation. The winch container with the three winches for the umbilical, streamer and gun array wire, respectively, was placed on the central part of the afterdeck (Fig. 5). On the starboard side, the compressor container, a gun workshop as well as streamer container and storage containers were placed.

Figure 5. The winch container and workshop container with storage containers above (top). Interior of compressor and workshop container (bottom).

At the very aft, a frame for the streamer and umbilical sheave were mounted. Wheels mounted along the rail for the coring equipment were used during deployment of the streamer (Fig. 6). After deployment, the streamer was connected to the umbilical and removed from the streamer sheave, followed by the deployment of the airgun cluster. The airguns were deployed by menans of the wire winch and the A-frame (operated by the ship's crew). Than the umbilical sheave was mounted in the frame. This setup with only one cable from the ship into the sea consisting of a heavy duty umbilical was designed to protect the seismic equipment as much as possible from ice impact and to facilitate a large depth for both airguns and streamer.

Cables were connecting the umbilical winch and the registration container placed on the port aft side of deck 4 (Fig. 7). Here the navigation software (NaviPac) and multichannel acquisition system (Geometrics CNT-2, SPSU, TGS-8, Winradio) were installed and operated. Drawings showing the container and equipment setup are enclosed in Appendix 1.


Figure 6. *Frame for streamer and umbilical sheave on the aft (left) and wheels for streamer along the rail for coring equipment (right).*


Figure 7. *Registration container on deck 4 and interior of the container.*

3. Reflection Seismic Acquisition Parameters

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For each survey line, a marine survey sheet with acquisition parameters and equipment serial numbers etc. was completed. The acquisition parameters are summarized in Table 1 below:

Table 1. *Summary of acquisition parameters*

Source	1 Sercel G and 1 Sercel GI gun
Chamber volume	605 cu.inch (250 + 250 + 105)
Fire pressure	200 bar (3000 psi)
Mechanical delay	16 ms
Nominal tow depth	20 m
Streamer	Geometrics GeoEel
Length of tow cable	43 m
Length of stretch section	50 m
No. of active sections	6 / 5 / 4 / 3
Length of active sections	300 / 250 / 200 / 150 m
No. of groups in each section	8
Total no. of groups	48 / 40 / 32 / 24
Group interval	6.25 m
No. of hydrophones in each group	8
Depth sensor	In each section
Nominal tow depth	20 m
Acquisition system	Geometrics GeoEel controller
Sample rate	1 ms
Low-cut filter	Out
High-cut filter	Anti-alias (=500 Hz)
Gain setting	6 dB
No. of recording channels	48 / 40 / 32 / 24
No. of auxiliary channels	4
Shot spacing	25 m
Record length	Variable between 8.5 and 11 s

4. Reflection Seismic Acquisition Geometry and Positioning

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Oden is equipped with GPS and other navigational systems that were used for navigation. For the reflection seismic data acquisition a separate GPS system was used. The navigation software NaviPac was used for logging and calculation of positions as well as logging of external data from the vessels Furuno gyro compass and the Kongsberg EM120 multibeam echo sounder. In addition, NaviPac generated the trigger signal for the seismic acquisition system.

4.1 Definition of Offset Points

In NaviPac a number of offset points were defined referring to the reference point of the vessel. The reference point is the midpoint of the vessel in the longitudinal and transverse direction in the horizontal plane and at the waterline in the vertical plane. A survey of the vessel was carried out in April 2007 by Metria and Sjökarteenheten at Landskrona Varvet in Landskrona, Sweden, using a total station and a theodolite. A local metric coordinate system was established and the x, y, and z coordinates of the reference point defined as 0 m, 0 m and 0 m respectively. The x-axis is defined across ship and positive in the starboard direction, the y-axis is defined along ship and positive in the forward direction, while the z-axis is vertical with positive upwards. Coordinates in this local coordinate system were now established for a number of fixed points and installations onboard *Oden*. Two drawings showing the measured points and a list of local coordinates are shown in Appendix 1.

A separate antenna was mounted for the GPS system used by the seismic acquisition system. The local coordinates of the antenna were defined measuring the distance in the x, y and z directions, respectively, to point 6 on the vessel (see Appendix 1). Similarly the local coordinates of the tow point of the umbilical (towing the airguns and streamer) was defined measuring the distance in the x, y and z directions to point 2 on the vessel. The vessel reference point, the GPS antenna and the umbilical tow point were all defined in NaviPac using their positions in the local coordinate system.

Additional offset points in NaviPac were the airgun midpoint and the 1st hydrophone of the first hydrophone group (channel 1) on the streamer. The local coordinates of these two points were defined measuring the length of the tow cable and the combined length of the jumper cable and the stretch section of the streamer assuming a tow depth of 20 m. The length of the tow cable was 40 m and with a tow depth of 20 m the resulting length of the tow cable along the y-axis was 31.5 m using Pythagoras' theorem. The airgun array was mounted in chains under the end of the tow cable and the length of the array is ca. 1.5 m. It is assumed that the position of the airgun array is at the end of the tow cable and hence the airgun midpoint was defined to have a layback of 32.25 m (31.5 + 1.5/2) relative to the tow point. The combined length of the jumper cable and stretch section up to channel 1 on the streamer was 53 m and, hence, the 1st hydrophone of channel 1 was defined to have an offset of 52.25 m (53 m – 1.5/2 m) relative to the airgun midpoint or 84.5 m relative to the tow point. The airgun midpoint and channel 1 were entered into NaviPac as offset points with coordinates relative to the tow point.

Drawings showing the location and coordinates of the offset points used and defined in NaviPac are attached as enclosure 4 and the offset coordinates are also given in Table 2 below.

Table 2. *Offset point coordinates*

Offset point	X (m)	Y (m)	Z (m)
Vessel reference point	0.0	0.0	0.0
GPS antenna	-11.25	13.40	25.30
Umbilical tow point	0.0	-53.5	4.65
Airgun midpoint	0.0 [1]	-32.25 [1]	-20.00 [1]
Streamer channel 1	0.0 [1]	-84.5 [1]	-20.00 [1]

[1] Relative to Umbilical tow point

4.2 Geodetic Reference System

The geodetic datum for all positions recorded or calculated (except offset for coordinates in the local vessel coordinate system) during the survey was WGS84 and no datum shift has been applied to the data. Hence all latitude and longitude coordinates are in WGS84 datum. In NaviPac the Universal Polar Stereographic projection (UPS) was used and all x and y coordinates are given in UPS projection and WGS84 datum. Furthermore, the reference meridian specified in NaviPac was 25° W. All coordinates processed in *NaviPac*, were transformed to the UPS projection, meaning that all logged geographical coordinates were transformed to UPS and back to latitude and longitude.Parameters for the WGS84 ellipsoid and the Universal Polar Stereographic projection are given in Table 3.

Table 3. *Geodetic reference system*

Geodetic datum	**WGS84**
Ellipsoid	**WGS84**
Semi-major axis (a)	6378137
Inverse flattening (1/f)	298.257223563
Eccentricity sq. (e^2)	0.006694379990
Projection	**Universal Polar Stereographic (UPS)**
Semi major axis	6.378.388 m
Inverse flattening	297
Scale factor at pole	0.994
Latitude of true scale	81° 07’ N
False easting	2.000.000 m
False northing	2000000 meters
Longitude from pole (reference longitude)	25° W

4.3 Navigation, Positioning and Trigger Generation

Runlines (the desired survey lines) were distributed to the bridge as waypoint coordinates and the vessel was navigated using its own navigation system. Because of the ice-conditions, large deviations from the distributed survey line were expected. A NaviPac Helmsmans display was not set up on the bridge to aid navigation. This is because the atual track of the vessel is governed by the local ice situation.

NaviPac received an updated GPS-antenna position and vessel gyro course every second and calculated real-time positions for the defined offset points. Positions for the vessel reference point and the umbilical tow point were calculated using the raw GPS-positions of the antenna, the local offset point coordinates and the gyro course of the vessel. Positions for the airgun midpoint and streamer channel 1 were calculated with reference to the position of the tow point using the drag method. Using the drag method the position of the offset point is calculated by projecting the travelled distance along the sailed route of the drag point, here being the tow point.

NaviPac was also used to generate the trigger signal for the seismic system. It was discussed whether to shoot on distance or on time. The advantage of shooting on distance is obviously shot points with a regular spacing. The disadvantage is, that in NaviPac the distance between shot points is not calculated along the actual sailed line but along the projection onto the active runline. This means that the shot point spacing will increase if the actual sailed line diverges from the runline (which was foreseen to happen quite often because of the ice-conditions). This shortcoming can be bypassed by defining a new runline parallel to the actual sailed line. Alternatively, it can be shot on time. The disadvantage of this would, however, be variations in shot point spacing according to changes of vessel speed. As the first few days of ice-breaking with and without *50 Let Pobedy* proved that the survey speed would vary a lot (effectively between 0 and 4-4.5 kn) it was decided to shoot on distance as shooting on time would not have been meaningful at all with the observed variations in survey speed. A shot point interval of 25 m was chosen.

4.4 NaviPac Log Files

In NaviPac three log files are generated during the survey. These are named yymmddZxxx with Z being either C, G or S for the custom, general or survey file format, respectively and xxx being consecutive numbers as new log files are generated during the day. Year, month and date are specifed by yy, mm and dd, respectively.

The custom file contains for every second:

- Time
- Event
- Filtered vessel position (position for vessel reference point) in UPS projection and in latitude/longitude
- LC605 gun (position for airgun midpoint) in UPS projection and in latitude/longitude
- Depth from multibeam echo sounder center beam (in meter below transducer)

The general file contains:

- General information about system settings (projections, offset points etc.)
- Time
- Event
- Filtered vessel position (position for vessel reference point) in the UPS projection and lat/long
- Tow point (position for umbilical tow point) in UPS projection and latitude/longitude
- LC605 gun (position for airgun midpoint) in UPS projection and latitude/longitude
- Streamer Ch1 (position for streamer channel 1) in UPS projection and latitude/longitude
- Gyro course from the vessel's gyro
- Depth in m below transducer (8 m below sea level) from multibeam echo sounder center beam
- Raw GPS position for antenna in latitude/longitude

The survey file encounters:

- General information about system settings (projections, offset points etc.)
- Time
- Event
- Filtered vessel position (position for vessel reference point) in the UPS projection and lat/long
- Tow point (position for umbilical tow point) in the UPS projection and Lat/Long
- LC605 gun (position for airgun midpoint) in the UPS projection and lat/long
- Streamer Ch1 (position for streamer channel 1) in the UPS projection and lat/long

On lines Lomrog07_01, 01A, Per, 01E and 02, the coordinate output to the SEG-D headers in Geometrics were x and y coordinates for the airgun midpoint and the latitude and longitude coordinates (in radians) of the vessel's reference point. The latitude and longitude are thus useless as they should have specified the airgun midpoint in degrees. Furthermore, x, y and latitude/longitude coordinates for the airgun midpoint are not logged in the custom-file for these lines.

In practice, the length of the tow cable was 43 m instead of 40 m and the tow depth of the airguns varied between 20 and 25 m, but the offset coordinates in NaviPac were never changed. The resulting tow length in NaviPac was 32.25 m, but with a tow length of 43 m and a tow depth of 20 m the resulting tow length should have been 36 m. Likewise, the resulting tow length with a tow length of 43 m and a tow depth of 25 m should have been 32 m. This introduces a potential variable error of 0-4 m in the shot point positions which can be regarded negligible as it does not have any impact on the processing geometry.

5. Reflection Seismic Data Acquisition

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5.1 Preparations

After passing Svalbard on August 15, 2007, a deployment test was performed with the seismic equipment while the ship was still in relatively ice-free waters. The deployment of the streamer and guns went very well, but there were some problems with getting the umbilical sheave into its position in the frame. A first attempt was performed with only 10 m tow length of the umbilical cable and the guns immediately behind the vessel. Increasing the tow length of the umbilical cable to 40 m was, however, enough to pull the sheave into the right angle and get it into the frame.

After deployment, a successful function test of the complete seismic acquisition system was carried out firing the guns at low pressure. The observed tow-depth of the guns at a survey speed around 4 knots was approximately 20 m as planned. The tow-depth of particularly the far sections of the streamer was somewhat deeper between 30 and 40 m, while the front sections were more or less located at a depth of 20 m as planned. It was therefore decided to balance streamer sections 3 to 6 with additional silicone oil. Also all "loose parts" on the airgun array were checked and tightened and secured as necessary.

5.2 Acquisition History

A line overview log was maintained during the survey. The log sheets are attached in Appendix 3. Below is a short description of important events during the reflection seismic survey. In Table 4, a summary of the line overview log is given, and in Table 5 an inventory of record files. A tape inventory log is attached as Appendix 3.

5.2.1 Line Lomrog07_01 and Line Lomrog07_02

The reflection seismic data acquisition was started on line Lomrog07_01 on August 19, 2007, around 01:30 UTC. An area was found where *Oden* following *50 Let Pobedy* was able to create 100-200 m open water behind the ship providing reasonable conditions for deploying the seismic equipment. Launching the streamer and umbilical went fine, but similar to the function test problems were encountered getting the umbilical sheave into the frame, even with 40 m tow-length of the umbilical. Low vessel speed may have caused reduced pull from the airguns in the water and thereby not helping getting the sheave in the right angle. It took some work with the wires in and out on the winch and the A-frame to get the sheave in place (Fig. 8).

Figure 8. *Mounting the umbilical sheave in the frame (left) and winch operator (right).*

The general ice conditions were far from favourable with relatively thick ice and large areas with pressure ridges. After only 6 km of data acquisition *50 let Pobedy* was stuck in the ice for a few minutes. It could be observed on the depth transducer readings from both airguns and streamer that they were sinking in the water column. It also appeared, however, that both airguns and streamer were in relatively safe conditions being washed away from the vessel by the propellers. During the following 24 hours, the umbilical was caught a number of times by large blocks of ice coming into the wash of the ship, causing or nearly causing the guns (and a few times also the streamer) to be lifted out of the water. Furthermore *Oden* was stuck in the ice several times. When *Oden* was stuck, *50 Let Pobedy* usually made a large turn and sailed along our port side to break the ice around *Oden* (Fig. 9). At around 01:30 UTC on August 20, 2007, *Oden* experienced problems with a main engine and as the ice conditions were very difficult it was decided to make a stop for maintenance, also leaving *50 Let Pobedy* time for regular maintenance. The seismic equipment was recovered and the airguns needed repair of a near field hydrophone and a hose collector-box, while the streamer was in good shape.

Figure 9. *50 Let Pobedy* passing *Oden* to break the ice (left) and *50 Let Pobedy* backing in front of *Oden* (right).

During the first 24 hours iof the survey, data acquisition terminated three times and restarted on lines Lomrog07_01A, Lomrog07_Per and Lomrog07_01E, respectively. The first time it was related to loosing the gun trigger signal, then to a breakdown caused by an attempt to change record length during acquisition, and eventually because of GeoEel software problems, see also Table 4.

After some hours, *Oden* gave up repairing the engine for the time being and steamed westwards for about 9 km trying to find better ice conditions. At around 13:00 UTC on August 20, 2007, the seismic equipment was redeployed to record line Lomrog07_02. Because of the ice conditions the ice-free water behind *Oden* was very limited. Based on experience from the times were *Oden* was stuck in the ice, it was decided to launch the equipment while lying still and keeping the nose up against the ice and using the wash from the propeller to push the streamer and the guns backwards away from *Oden* (Fig. 10). This worked very well and the only problems were once again getting the sheave into its position in the frame. Also this time it took some work with the wires in and out on the winch and the A-frame to get the sheave in place.

In the following 12 hours the umbilical was again often caught by large blocks of ice causing or nearly causing the guns to be lifted out of the water and *Oden* was stuck in the ice many times. *50 let Pobedy* sometimes turned around and sailed along our port side and sometimes went backwards to "pick us up".

Around 01:00 UTC on August 21, 2007, the streamer got caught in the ice and all communication to the streamer was lost. The air guns, the stretch section and one out of six active streamer sections were recovered. A helicopter search was performed to try to find the remaining streamer sections, but without success. After the loss of the five streamer sections it was decided to move southwest to the next seismic line and hope for more favourable ice conditions there.

5.2.2 Line Lomrog07_03

Around 16:00 UTC on August 26, 2007, acquisition of line Lomrog07_03 started. The equipment was deployed lying still in the ice thereby using the wash from the propeller to push the streamer and the guns backwards away from *Oden*. Getting the sheave into the frame was more successful this time using a robust handmade steel pipe as lever when tilting the sheave in the right angle (Fig. 10). For the next seven hours the umbilical was caught by large ice blocks very often and *Oden* was frequently stuck in the ice. Around 23:00 UTC communication to the streamer was lost and all the equipment therefore recovered. It turned out that two live streamer sections were damaged. They had been caught in the ice and were both punctured and one had broken wires inside. The damaged sections were removed and one additional section was mounted.

Figure 10. *Space of ice-free water available for deployment of equipment (left) and mounting umbilical sheave in frame using handmade lever (right).*

Around 01:00 UTC on August 27, 2007, the equipment was deployed again while lying still, this time with five active sections. For the next 3 hours *Oden* was stuck in the ice most of the time and the umbilical was caught by large ice blocks 3 times. The third time communication to the streamer was lost and the equipment was recovered. However, only the airguns were brought onboard while the stretch section and six live sections were lost. Parts of the streamer could be observed at two different places in the ice and several attempts were made from the ship's helicopter to pull the streamer up from the ice (Fig. 11). After trying for some time without success, it was decided to let *50 Let Pobedy* try to break the ice around the streamer while the helicopter was pulling. After trying this for a while, it was decided to let *50 Let Pobedy* try a rescue operation on its own. They lowered a person down on the ice with the crane to tie a rope on to the streamer. Then they moved slowly forward to break the ice around the streamer and tried to recover it while gliding back. They succeeded in recovering the stretch section, two live sections and two A/D converters. The equipment was however heavily damaged and it will take thorough testing to verify which parts eventually can be used again.

5.2.3 Line Lomrog07_04

Due to the heavy ice conditions norh of Greenland it was decided to acquire a seismic line in an area off Northeast Greenland and on September 12, 2007, the starting point for line Lomrog07_04 was reached. Around 19:00 UTC the equipment was deployed. Three new streamer sections had been supplemented with a repaired fourth section. Prior to deployment the streamer was tested thoroughly on deck, but unfortunately had a failure after deployment. After recovery and some hours of trouble shooting it turned out that the A/D converter on section two had to be replaced. Around 00:30 on September 13, 2007, acquisition of line Lomrog07_04 in ice-free waters was started. During the acquisition we entered into ice-filled waters (8/10), but neither *Oden* nor the seismic equipment were affected by the ice. Data acquisition was, however, during the following 24 hours terminated twice and subsequently restarted on lines Lomrog07_04A and _04B, respectively. The first event was related to a broken air hose in the airgun array. The second interruption was caused by an unrecoverable fault in streamer section 4, which was then removed. Around 01:15 on September 14, 2007, line Lomrog07_04B was terminated as planned at end of line (EOL).

Figure 11. (top) Attempt to recover lost streamer sections by helicopter and by a combination of *50 Let Pobedy* and helicopter. (left) *50 Let Pobedy* streamer rescue operation.

Table 4. *Summary of line overview log*

Line	Record length (sec)	Duration (hours)	No. of shots	Shots per hour	No. of times being stuck in the ice no. per hour	No. of times parts of the equipment was out of the water	No. of times mis-triggering because of survey speed
LOMROG07_01	11	4	497	124	5 / 1.3	2	2
Comments	Guns not shooting on first ca. 50 shots Line terminated because of loosing trigger signal						
LOMROG07_01A	11 / 9	14.5	2823	195	9 / 0.6	2	2
Comments	Shot 3233-3472 only 9 s record time NaviPac resetting event numbers, after event 3329 comes event 137 Line terminated because of breakdown caused by new attempt to change record length during acquisition.						
LOMROG07_Per	9.5	0.25	48	192	0 / 0	1	0
Comments	Problems with GeoEel software, testing old version of GeoEel software Restarting shot numbers from 1. Line terminated because of problems with old version of software.						
LOMROG07_01E	9.5	4.5	466	104	6 /1.3	0	0
Comments	Restarting system with the latest version of GeoEel software. Resetting streamer modules at the end of the line. Line terminated because *Oden* needed to perform engine maintenance.						
LOMROG07_02	9.5	12	904	75	16 / 1.3	2	2
Comments	1 hour break in shooting while *50Llet Pobedy* runs a "navigation route" in the ice Line terminated due to loss of streamer.						
LOMROG07_03	8.5	7	631	90	10 / 1.4	12	0
Comments	Line terminated due to failure of 2 streamer sections.						
LOMROG07_03A	8.5	3	49	16	Mostly stuck	3	0
Comments	Only five streamer sections, 44 channels. Line terminated due to loss of streamer.						
LOMROG07_04	9.5	16	5265	329	0	0	0
Comments	Only four sections, 36 channels. Line terminated because of broken air hose in airgun array.						
LOMROG07_04A	9.5	1.75	464	265	0	0	0
Comments	Only four sections, 36 channels. Line terminated because of failure in last streamer section.						
LOMROG07_04B	9.5	3.25	972	299	0	0	0
Comments	Only three sections, 28 channels. Line terminated as planned at EOL.						

Table 5. *Record inventory*

Line	First record	Last record	NaviPac log files	Tape	Geometrics log files
Lomrog07_01	100.sgd	596.sgd	070819x000.npd	101	Lomrog07_01.0000 Lomrog07_01.0000.depth Lomrog07_01.0000.gather1
Lomrog07_01A	650.sgd	3472.sgd	070819x000.npd	102	Lomrog07_01A.0000 Lomrog07_01A.0000.depth Lomrog07_01A.0000.gather1
Lomrog07_Per	1.sgd	48.sgd	070819x000.npd	103	Lomrog07_Per.0000 Lomrog07_Per.0000.depth Lomrog07_Per.0000.gather1
Lomrog07_01E	4000.sgd	4464.sgd	070819x000.npd	104	Lomrog07_01E.0000 Lomrog07_01E.0000.depth Lomrog07_01E.0000.gather1
Lomrog07_02	4465.sgd	5368.sgd	070820x001.npd 070820x002.npd 070821x000.npd 070821x001.npd	105	Lomrog07_02.0000 Lomrog07_02.0000.depth Lomrog07_02.0000.gather1
Lomrog07_03	1.sgd	631.sgd	070826x000.npd 070826x001.npd 070826x002.npd 070826x003.npd 070826x004.npd 070826x005.npd 070826x006.npd	106	Lomrog07_03.0000 Lomrog07_03.0000.depth Lomrog07_03.0000.gather1
Lomrog07_03A	665.sgd	713.sgd	070827x000.npd	107	Lomrog07_03A.0000 Lomrog07_03A.0000.depth Lomrog07_03A.0000.gather1
Lomrog07_04	1.sgd	5265.sgd	070913x000.npd	108	Lomrog07_04.0000 Lomrog07_04.0000.depth Lomrog07_04.0000.gather1
Lomrog07_04A	5268.sgd	5731.sgd	070913x001.npd	109	Lomrog07_04A.0000 Lomrog07_04A.0000.depth Lomrog07_04A.0000.gather1
Lomrog07_04B	5737.sgd	6708.sgd	070913x002.npd	110	Lomrog07_04B.0000 Lomrog07_04B.0000.depth Lomrog07_04B.0000.gather1

6. Gun and Streamer Depth Behaviour - Noise Conditions

By Holger Lykke-Andersen, Department of Earth Sciences, University of Aarhus

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The following notes are based on depth recordings during the acquisition of the seismic line 3 of the Lomrog 2007 expedition. Depth transducers were mounted on the gun-array frame and in the front end of each active streamer section.

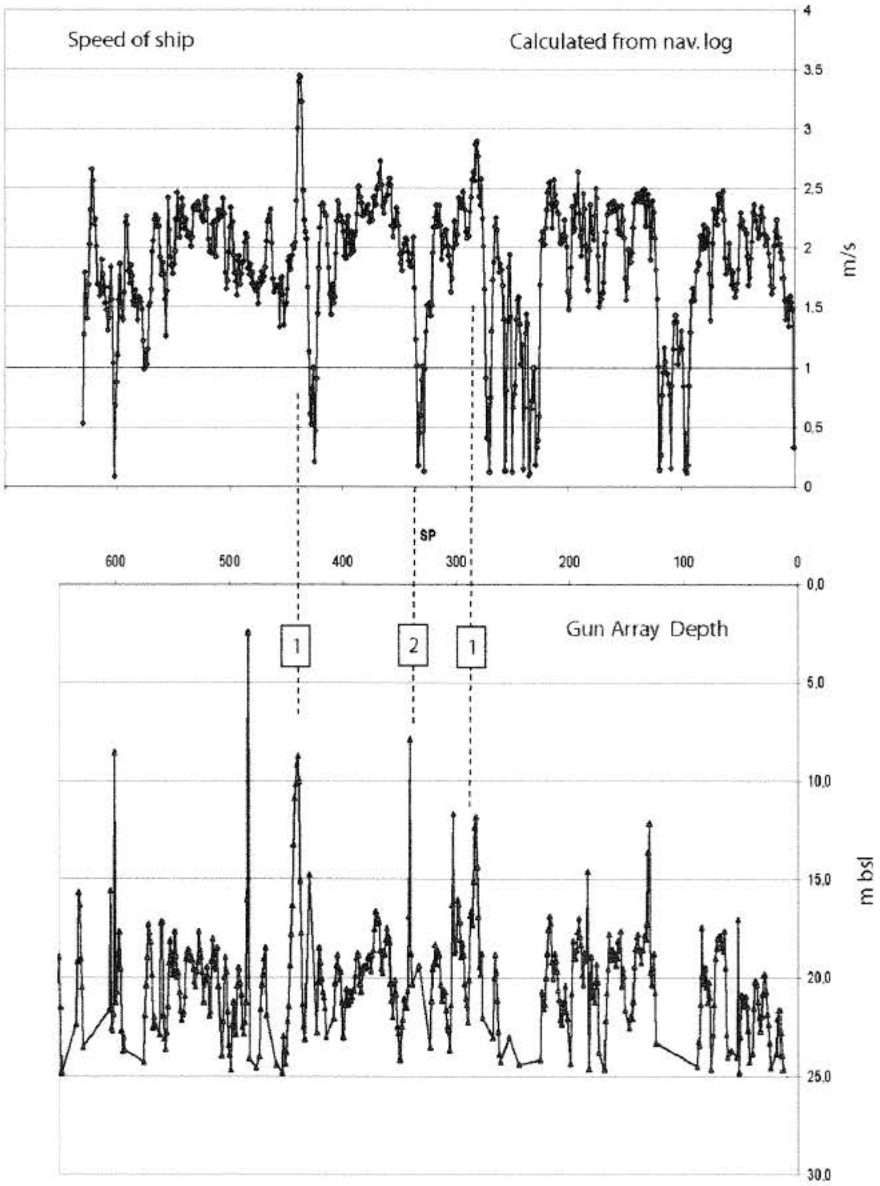


Figure 12. *Depth values of the air gun array on line 3 (bottom) shown together with the ship's speed (top).*

6.1 Gun-Array Depths

The gun-array depths were recorded and filed by the gun-trigger-unit (TGS 8). Depths were recorded at each shot position, but in about 30% of the cases the recorded depth was declared "invalid" in the data file. The failure is probably caused by ice clogging the hole which provides the transducer's hydrostatic connection with the surrounding water masses. All recorded, valid depths along line 3 are depicted in Fig. 12. The maximum depth for the gun-array is given by the total length of the umbilical below sea level (35 m) plus the length (3 m) of the suspension chains carrying the gun-array. Despite this the maximum observed depth is 25 m bsl. A depth limitation in the transducer may be the explanation.

Most of the time the gun-array stayed within the depth interval 18- 23 m. Occasionally it raised to shallower levels with 2 m bsl being the shallowest observed.

The moderate variations in the general depth-region (18-23 m) may be attributed mainly to variations in the ships speed and propeller thrust whereas the extreme uplifts have two different causes: temporary increase in the ships speed (event 1 in Fig. 12) or uplift by ice (event 2 in Fig. 12). A cross-plot of the gun-array depth versus the ship speed is shown in Fig. 13.

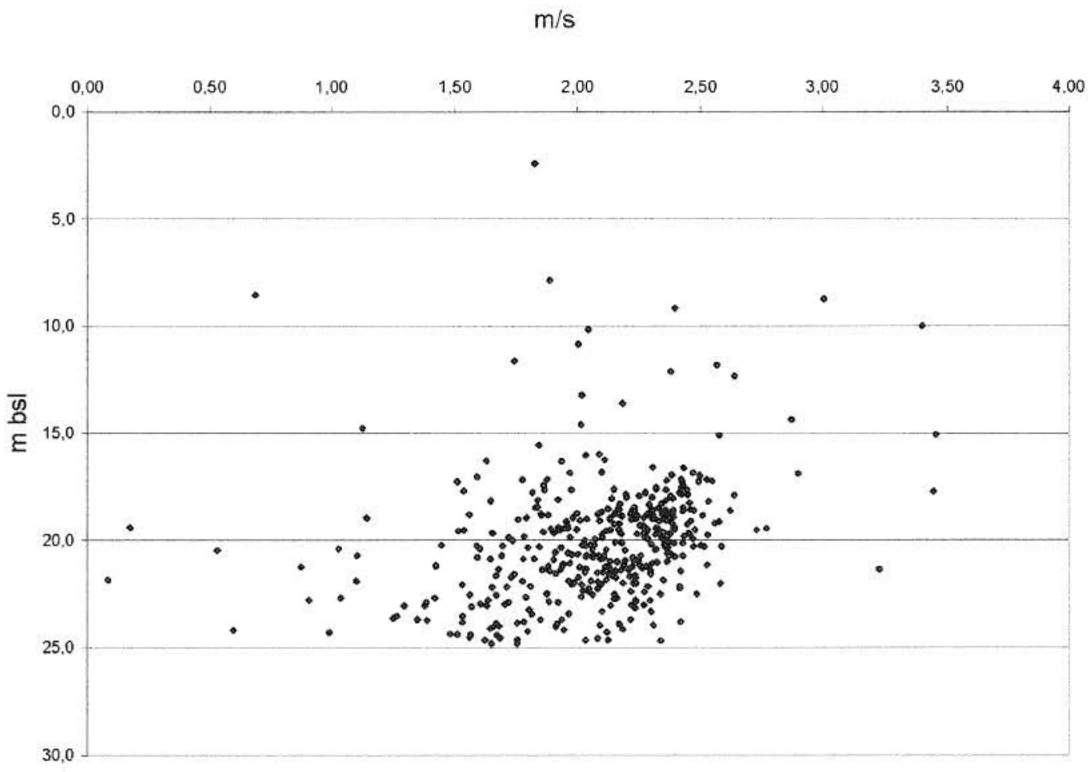


Figure 13. *Cross-plot of the gun array depth versus the ship's speed.*

6.2 Streamer Depths

The depth information from the six depth transducers was recorded and filed on the PC running the Geometrics CNT-2 seismic controller software.

Depths were recorded on one of the six transducers after each shot. Thus, the depths for all six transducers were recorded after six consecutive shots. Or, the depth for each of the transducers was updated at distance intervals equal to the distance between six shot locations i.e. 150 m.

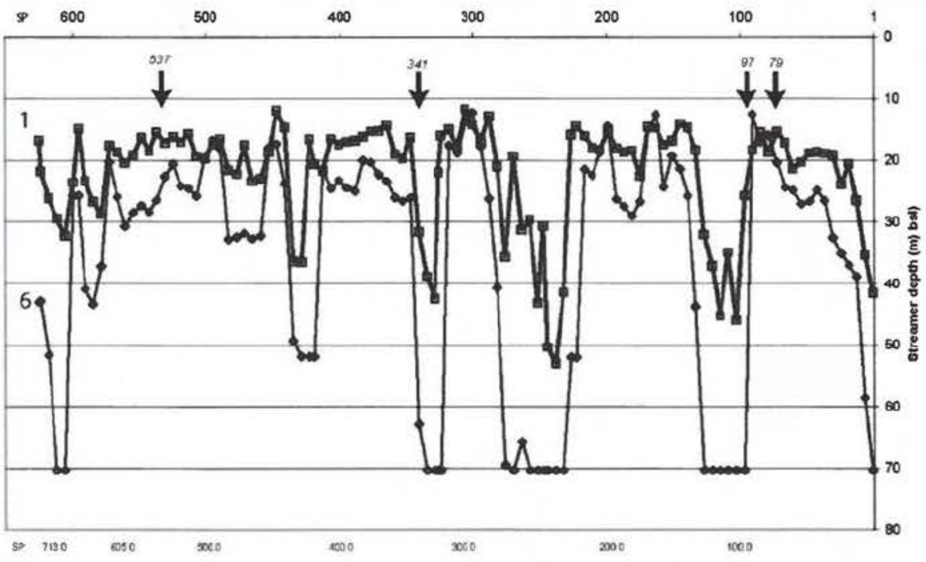


Figure 14. *Streamer depth variations along line 1. The front section (1) and the rear section (6) are shown.*

Fig. 14 illustrates the streamer depth variations along the line. For simplicity only the behavior of the front (1) and the rear (6) sections are shown. The depths vary in the interval 12 m to > 72 m. (The maximum recordable depth for the transducers is 72 m). It should be noted that depths for both sections 1 and 6 are plotted with reference to the same shot point (on the x-axis). Because of the skewness in the depth recordings this means that the curve representing section 6 is shifted about 150 m or six shot points to the right (on Fig. 14) relative to the curve for section 1.

The implication of the skewed recording procedure is that only approximate descriptions of the streamer behavior can be obtained. This, for example means that the "snapshots" of the length profiles of the streamer as shown in Fig. 15 are not strictly true. The depths indicated along the streamers are not coeval. The time-distance between consecutive observations is at least one minute depending on the ship speed. Thus, the front-end points (section 1) are recorded minimum five minutes before the rear-end points (section 6).

The four streamer profiles in Fig. 15 represent shot points selected as indicated in Fig. 14. The circumstances at shot points 79 and 537 are considered as "normal" in the sense that it represents a situation after a period with relatively static conditions. In such cases the streamer seems to keep approximately the same depth (ca. 20 +/- 5 m) as the gun-array throughout the whole streamer.

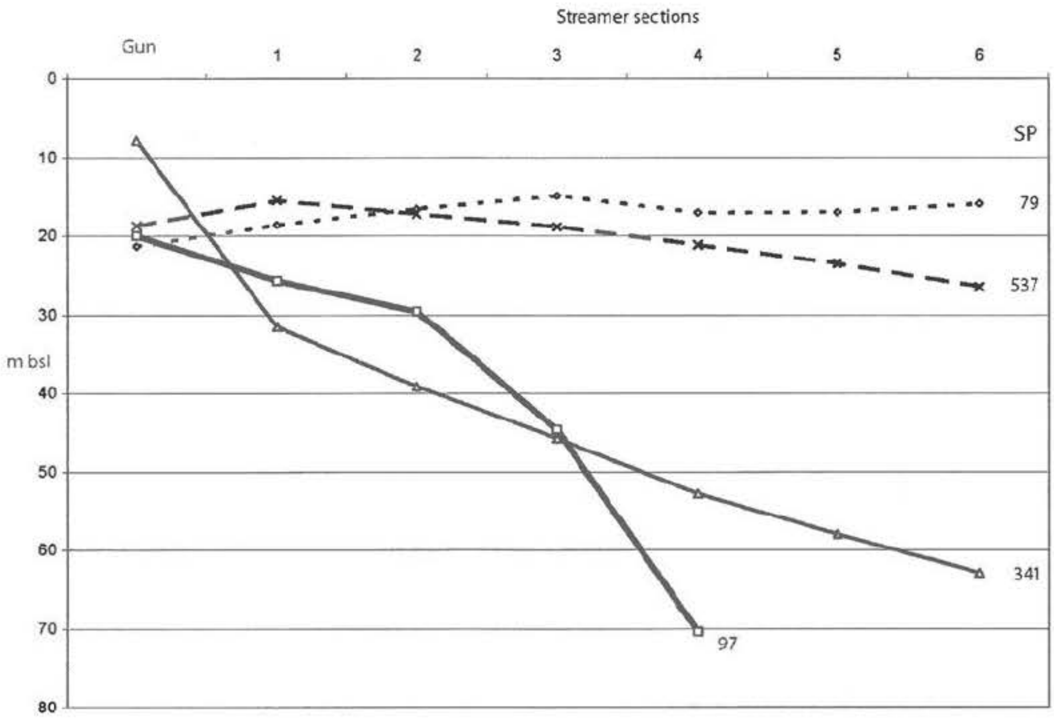


Figure 15. *Streamer-depth profiles for selected shot points (SP)*

Shot points 97 and 341 are meant to illustrate the situations when the ship is decelerating (shot point 97) and accelerating (shot point 341) (cf. Fig. 12). During deceleration the streamer dives with the tail end first. It should be noted that section 4 is at the maximum recordable depth, but it may well be at greater depth. Sections 5 and 6 exceed the maximum recordable depth of 72 m. Linear extrapolation indicates that the tail end of the streamer may be at depths of 170 m or more. It should be noted that 3 to 4 kg of lead were mounted to the tail end of the streamer.

Seismic noise

Line Lomrog07_03 was acquired in an area with an ice coverage of 100 % and with measured ice thickness close to 5 m and with many pressure ridges. Under these circumstances the icebreaker *Oden* had to apply up to full power to maintain progress along the seismic line. The implication of this was the production of very strong cavitation noise from the propellers. This noise was often strongly amplified when ice clogged the front end of the cylindrical shield around the propellers.

The fierce turbulence in the wake was most likely also a contributor to the noise. The noise level was calculated for each shot as the average RMS-amplitude in the TWT-window 2-4 sec (in the water column). An overview of the variations along the line is given in Fig. 16 where the noise amplitude is presented as running mean values calculated over five shot points.

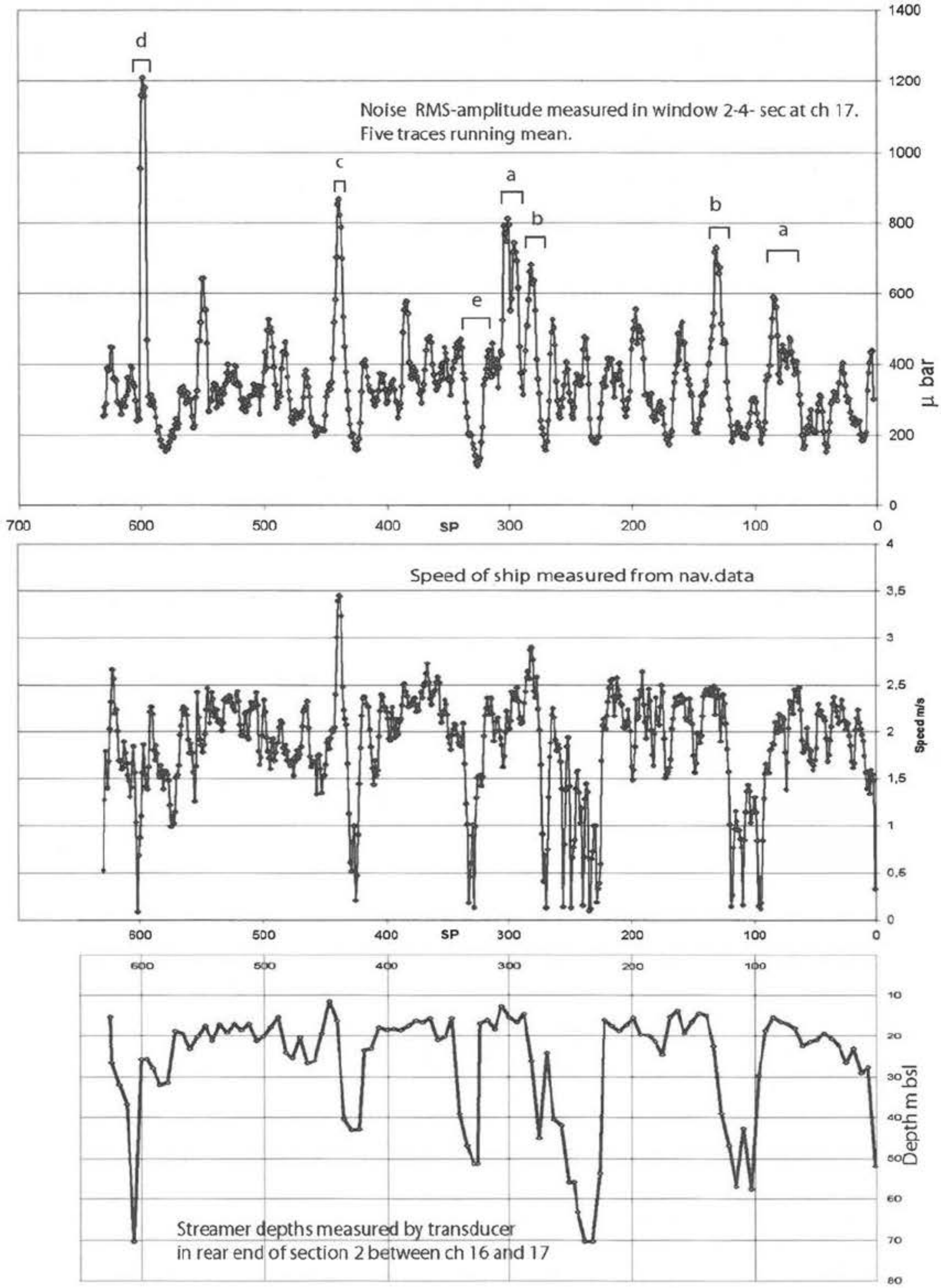


Figure 16. *Noise levet (top), ship speed (centre) and streamer depth at rear end (bottom).*

The general noise level falls in the interval 200-400 µbar with plenty of strong noise bursts on top of it. The noise level is 1-2 orders of magnitude higher than noise encountered under normal conditions.

By comparisons between the noise record and the records of speed and streamer depth it is found that high amplitude bursts of noise formed under a variety of circumstances which may be related to the action of the propellers. A number of noise bursts (marked a-d in Fig. 16) have been interpreted as follows:

a) peak amplitudes 6-800 µbar immediately before the ice breaker is stopped by the ice. It seems likely that the reason is that the thrust is maximized in an attempt to maintain the forward movement of the ship;

b) peak amplitudes around 700µbar in two cases immediately after a standstill. In that situation a high thrust may be needed in order to accelerate the ship;

c) peak amplitude ca. 850 µbar in a situation where it was possible to increase the speed to ca. 3.5 knots. It is unlikely that the elevated noise level is a simple consequence of the relatively high speed. The fact that the higher speed pulled the streamer to relatively shallow depth (ca 10 m) and thereby possibly carried it into the turbulent wake may be the reason for the increased noise;

d) peak amplitude 1200 µbar during a short standstill. The explanation for this unexpected relationship may be that the icebreaker avoided to be captured by the ice by increasing the thrust for a short while.

Except for this one incident most intervals with low speed of the ship are characterized by relatively low noise levels. One of the most prominent examples is marked with “e” in Fig 16.

The Lomrog07_03 profile was acquired under extreme difficult conditions. The data are infested by massive noise most of which is believed to originate from the ice breakers propellers. Furthermore, the data are strongly affected by the large depth variations of the streamer – mainly controlled by the unavoidable variations in speed of the ship.

The depth data have shown that the gun and streamer moves in the water as expected at about 20 m depth, but only when the speed is approximately constant. The variations in speed (0 to 3.5 knots) induces level variations of the streamer in the interval 10 to >100 m. This translates into TWT-shifts up to 60 to 70 ms in the reflections. Time shifts in that order of magnitude have to be corrected for by static corrections in the processing.

The necessary data for obtaining acceptable static corrections is precise depth information for each shot – gun and streamer - along the line. The performance of the depth monitoring system used under the Lomrog07 expedition must be improved to allow updating of all depth transducers for each shot. Nevertheless, it has already been demonstrated that a stacked section of acceptable quality can be obtained by careful processing of the data acquired with the current system (see chapter 7).

7. Processing of Seismic Reflection Data

By Trine Dahl-Jensen, Geological Survey of Denmark and Greenland

Onboard processing was carried out on a ProMAX system running on a laptop computer with an external hard disk and LINUX as operating system. Below a status of processing done onboard is given with recommendations of further processing. The processing presented is not final.

7.1 Shot Numbering and Record Numbers

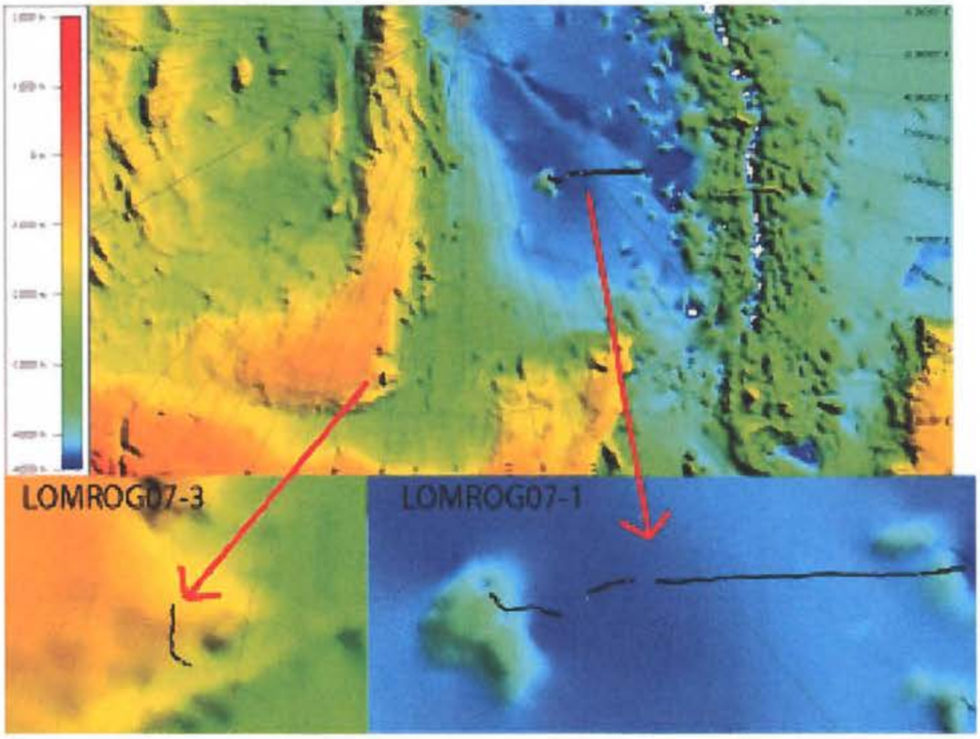


Figure 17. *Position of the seismic lines acquired in the Arctic Ocean.*

NaviPac produces event numbers each time a trigger is sent to the Geometrics system. This number is not unique to the seismic lines, as the numbers restart from a lower number on occasion (new runline, re-start of system etc). The record numbers from Geometrics are used as "ffid" (field record number) and as the unique identifier. On LOMROG07-1 (consisting of sublines 01, 01A, Per, 01E and 2) the 48 records in subline Per are not in sequence as the numbering was reset for this small part of the line. The ffid numbers in the ProMAX files in the folder "Per" are set to 3500+record number from Geometrics. Then the numbering is in sequence with the other sublines. LOMROG07-3 was recorded in two parts; 03 and 03A. LOMROG07-4 was acquired in three parts (4, 4A, 4B) but was not processed onboard.

Table 6. *Data storage of individual sublines*

LOMROG 07		Area:	North of Greenland			
Cartridge	Line	Date	Record	Sample	File/shot point	
		d - m - y	length	Interval (ms)	range	
100	TEST	15-Aug-07	11000	1	1	190
101	01	19-Aug-07	11000	1	100	596
102	01A	19-Aug-07	11000	1	650	3232
102	01A	19-Aug-07	9000	1	3233	3472
103	Per	19-Aug-07	9500	1	2	48
104	01E	19-Aug-07	9500	1	4000	4456
105	02	19-Aug-07	9500	1	4465	5368
106	03	26-Aug-07	8500	1	1	631
107	03A	27-Aug-07	8500	1	665	713

7.2 Navigation

NaviPac information
An information string from NaviPac is sent to the SEGD headers. For LOMROG07-1 the format is:

19:41:14.486, 0,2028915.35,1727379.76,1.53,-0.33,4557.56
eiva time eivano gunx guny shiplat shiplon waterdepth

The time is in UTC, the gun position (gunx, guny) is specified in meters in Universal Polar Stereographic coordinates (see below), the latitude and longitude are in radians. The water depth is in meters under the transducer (which is 8 m under sea level).

This information is read to the ProMAX headers. The format & byte positions are:

Start byte		Format name	Comment
129	2c	timeh	time hour part
132	2c	timem	time minute part
135	2c	times	time second part
138	3c	timesd	time second decimal
142	5c	eivano	Eiva/NaviPac event number
148	7c	sutmxm	gun x meter
156	2c	sutmmd	gun x decimal meter
159	7c	sutmym	gun y meter
167	2c	sutmymd	gun y decimal meter
179	5c	wd	water depth

For LOMROG07-3 the water depth was at byte-position 181 5c as the latitude and longitude were specified in decimal degrees.

Eiva (NaviPac event number) is stored as a separate header EIVANO in the ProMAX trace headers. The gun x and y positions are in Universal Polar Stereographic projection with a scale factor of 0.994 at the pole and true scale parallel at 81° 07'N. Reference longitude is 25°W. There is a false northing and easting of 2.000.000 m.

7.3 Shot Time (for Sonobuoys)

Then the following headers are defined:

eivatime = timeh*10000 + timem*100 + times + timesd/1000.0
souutmx = float(sutmxm) + sutmxmd/100.00
souutmy = float(sutmym) + sutmymd/100.00

For sonobuoys:
On auxiliary channel 3 (corresponding to channel 51, when six active sections were used) a PPS pulse (on every second mark) is read in. The true shot time is extracted: The time to the first second pulse after start of recording is picked (FB_pick) and then the shot time is calculated by:

t_time s = I nt(times+(timesd + 1100.0)/1000.0)
t_tsd = 1000.0 – FB_pick
shottime = timeh*10000.0 +timem*100.0 + t_times*1.0 + t_tsd/1000.0

where the trigger time from Navipack is read from the Eiva-string. There is a delay of close to 1100 ms before the actual trigger. From the Eiva-time the second pulse on auxiliary channel 3 is identified (t_times) and the time from the shot break to the pulse is subtracted to give the true shot time.

The projection of the gun x and y positions is in Universal Polar Stereographic projection with a scale factor of 0.994 at the pole and true scale parallel at 81° 07'N. Reference longitude is 25°W. There is a false northing and easting both of 2.000.000 m.

An output file is written

for LOMROG07_1:
ffid souutmx-2000000 souutmy-1000000 shot time wd

and for LOMROG07_3:
ffid souutmx-1000000 souutmy-1000000 shot time wd

7.4 Geometry

The geometry is assigned in a couple of steps with the assumption that the profile is projected onto a straight line; i.e one azimuth, which is a more simple approach. ffid is the unique parameter.

1. Set up of a 2D marine geometry, using the module "auto 2D" in ProMAX to create the database. Edit the sources spreadsheet so source numbers equal ffid. Assign, bin and finalise the geometry. Now a valid geometry database exists, which assumes that shots are equally spaced on a line.

2. Read all data and assign geometry inline (to assign SIN numbers). In same flow, use header/database transfer to write the header values "souutmx" and "souutmy" to source positions in the SIN database, tied to "ffid".

3. Rerun the 2D marine geometry tool and edit the sources spreadsheet for errors, non-existing shots, interpolate missing positions etc. Use auto-azimuth to get the best-fit azimuth. Reassign midpoints, re-bin and finalise database again.

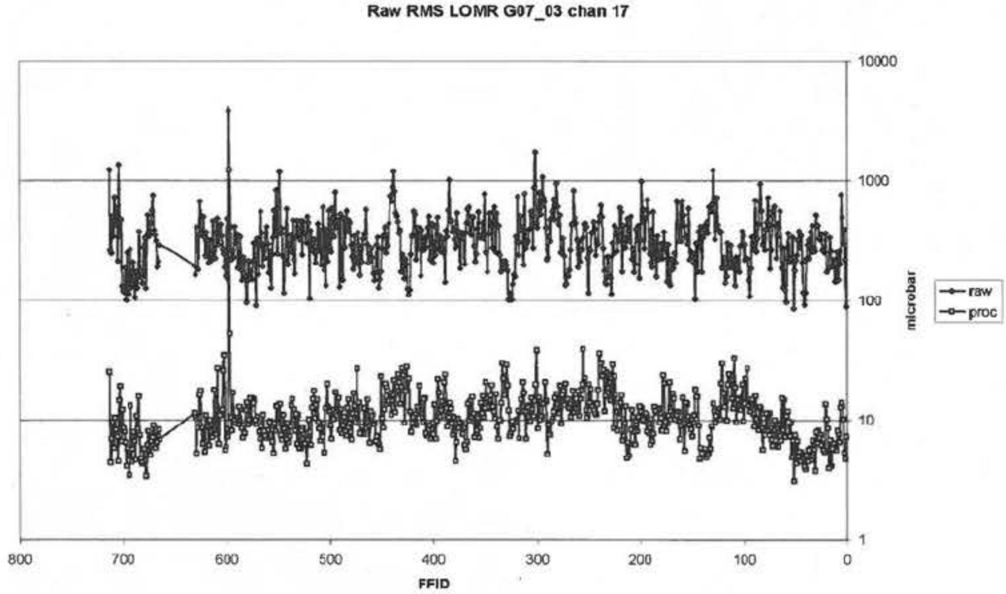
Now the geometry database is ready to be applied to the data, projected onto a straight line. The data acquired are not on an absolutely straight line, but surprisingly close. A test with true crooked line processing will be carried out after the cruise.

7.5 Noise

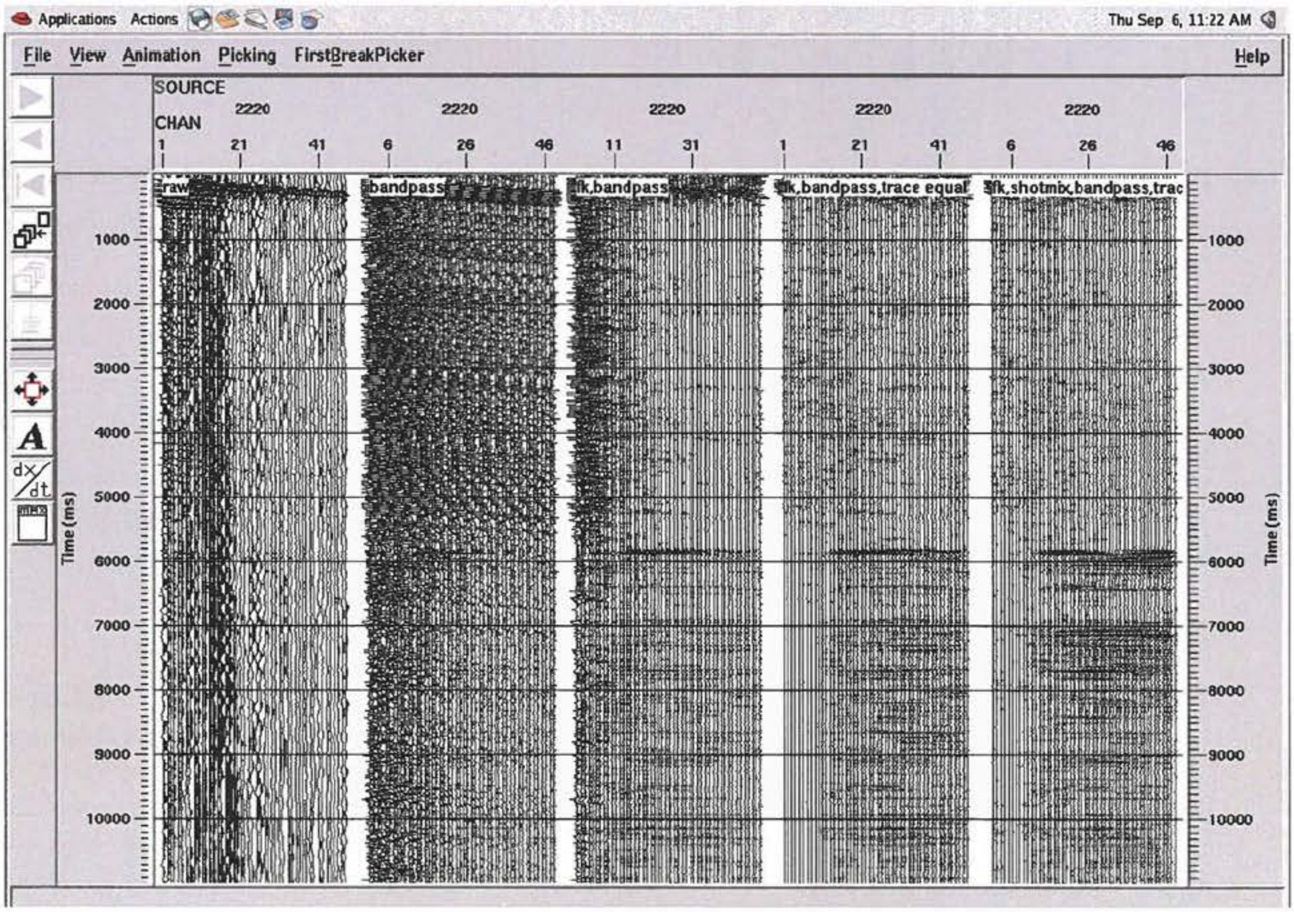
The data acquired are very noisy. *Oden* is built for icebreaking and the noise from the ice itself and the cavitation noise are high.

A series of tests for noise elimination was carried out consisting of editing (extraordinary noisy shots and traces were marked and eliminated, shots with an additional triggered shot edited to eliminate the extra trigger); an fk-filter to eliminate noise from *Oden* propagating with water velocity, a time and space variant band pass filter designed to eliminate unwanted noise as well as enhancing the primary data; and a shot-mix where each channel from three neighbouring shots are mixed with a weighting factor of 1-2-1 between shots.

Fig. 18 shows the noise level (in μbar) on both raw and processed data. The level after processing (approximately 10 μbar) is acceptable considering the conditions under which the data were acquired.



Raw RMS LOMR G07_03 chan 17
10000
1000
100
10
1
microbar
raw
proc
800
700
600
500
400
300
200
100
0
FFID



Applications Actions
Thu Sep 6, 11:22 AM
File View Animation Picking FirstBreakPicker
Help
SOURCE
CHAN
2220
raw
bandpass
fk,bandpass
fk,bandpass,trace equal
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6000
7000
8000
9000
10000

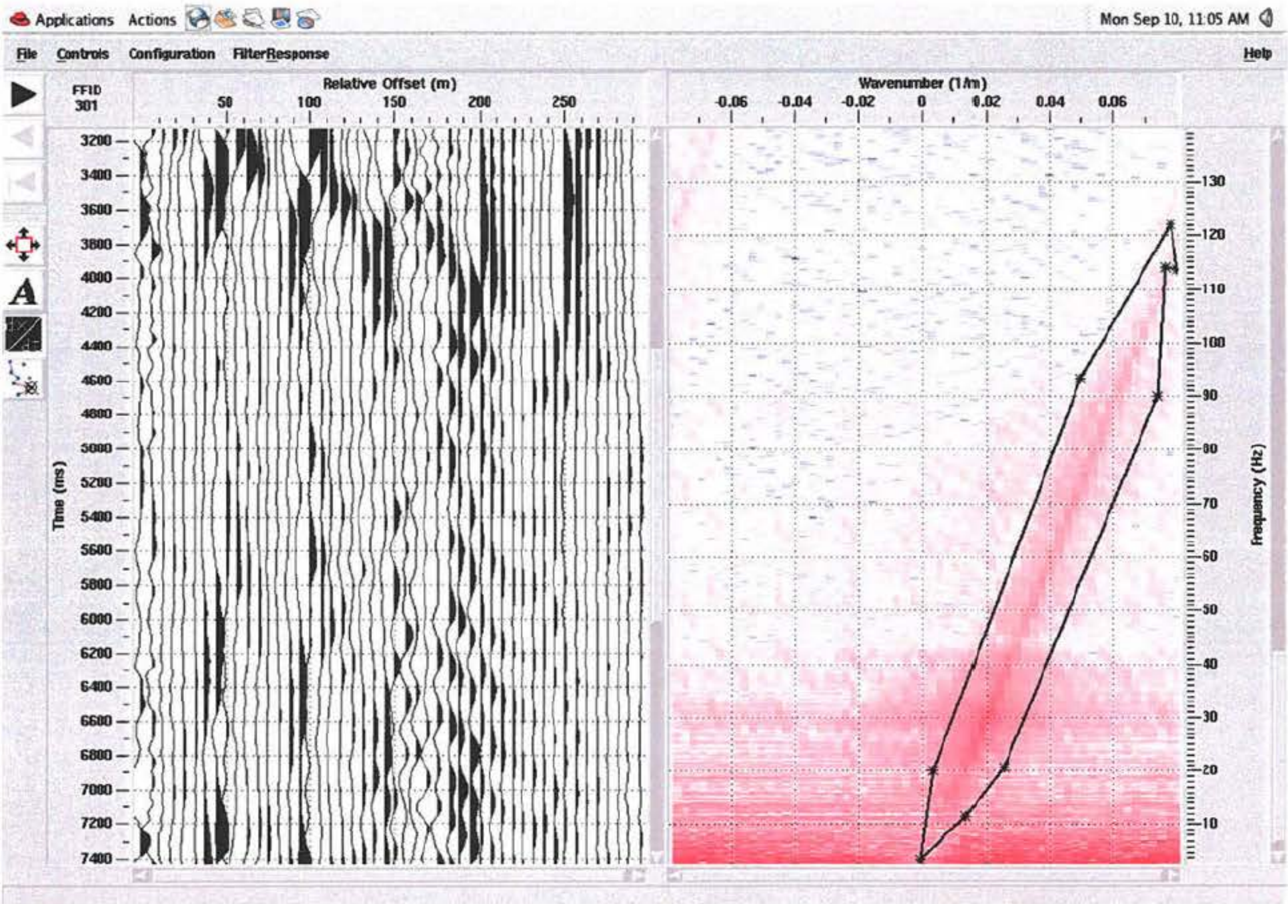


Figure 18. *Opposite page top: Noise levels of raw and processed data on LOMROG line 3. Opposite page bottom: Panel of shot gather with various processing steps applied to. Top: fk-spectrum of a shot gather with the direct wave marked by a black line.*

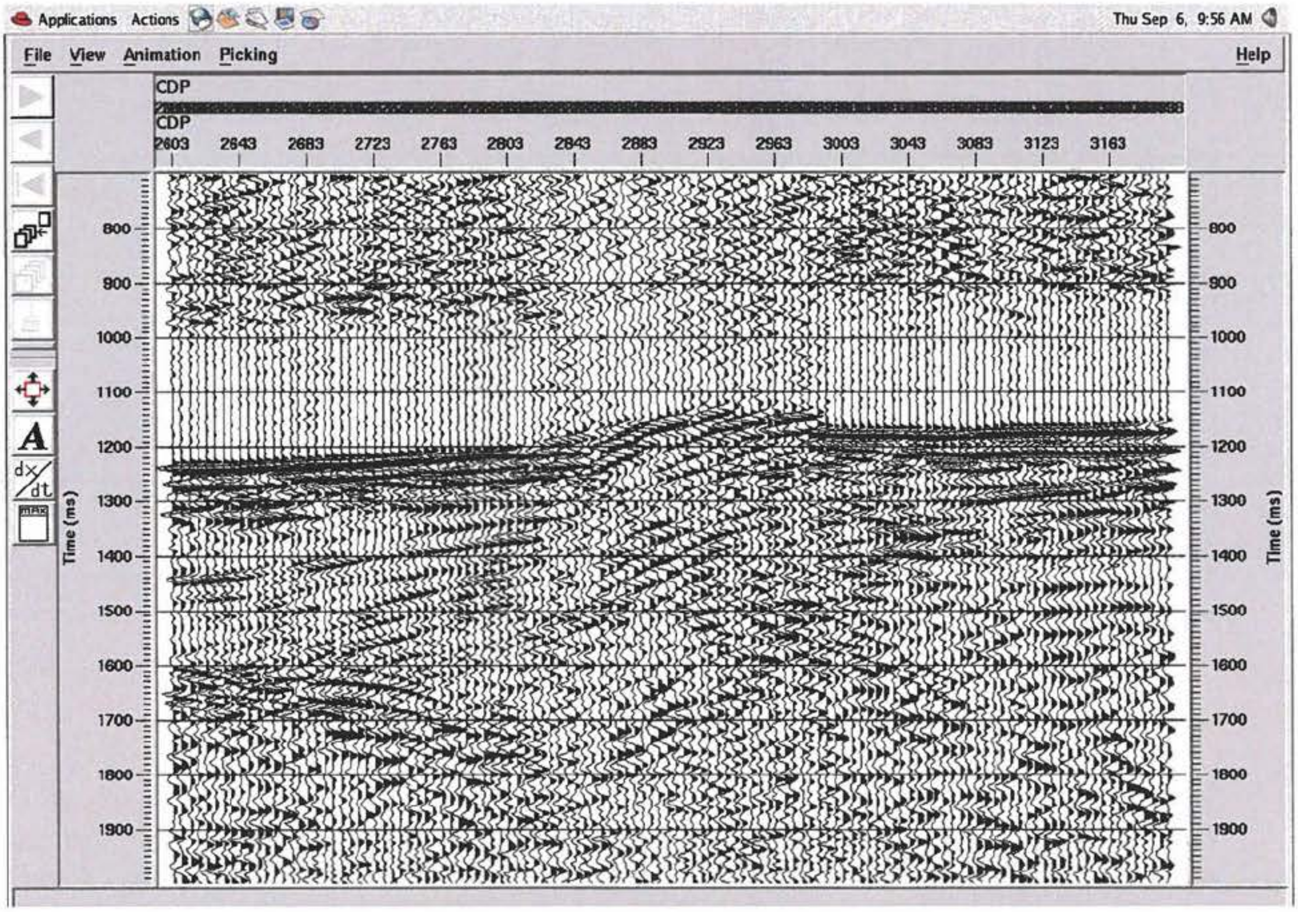
7.6 Statics

Gun delay: -16 ms (to be applied before normal move-out (NMO)).
Datum static: streamer nominal 25 m, gun nominal 20 m, average 22.5 m.
With a water velocity of 1440 m/s, the static correction is +31 ms (to be applied after NMO).

7.6.1 Streamer Statics

The speed of the ship during the data acquisition was very variable; from over 5 knots to standstill. When *Oden* was stuck in ice, the streamer sank; streamer sections furthest behind the ship sank deepest (see section 6.2). This resulted in early arrivals on the deepest parts of the streamer. The sections of the stack when *Oden* was stationary are very noisy and incoherent. Additional noise was created when *Oden* used full engine power to push forward through the ice. On LOMROG07-3, the streamer depth was recorded for each shot, but as only one depth sensor reading was updated for every shot, a full update was at intervals of six shots. In addition, all values over 70.32 m were recorded as 70.32 m. On LOMROG07-1, the streamer depth was only updated at large intervals.

For LOMROG07-3 the streamer depths recorded were interpolated both between shots and along the streamer to give a receiver depth at each channel for each shot. When the recorded depth was >70 m, previous values were used to extrapolate. These depth values were applied as a streamer static, reducing the streamer depth to a nominal 20 m. Traces with depths >55 m were eliminated from the stack, which improved the stack in the noisy sections. This procedure is not possible for lines LOMROG07-1 and 4 as only few streamer depths were recorded on these lines.



However, in the noisy sections it would be possible to a) perform an NMO b) pick the seabed reflection c) correct it to the same value as the near traces across each shot (provided the seabed is flat, a very good assumption for this line). This would have the same effect as the static correction described above but a test for automatic picking of the seabed reflection indicates that many of the picks have to be edited manually.

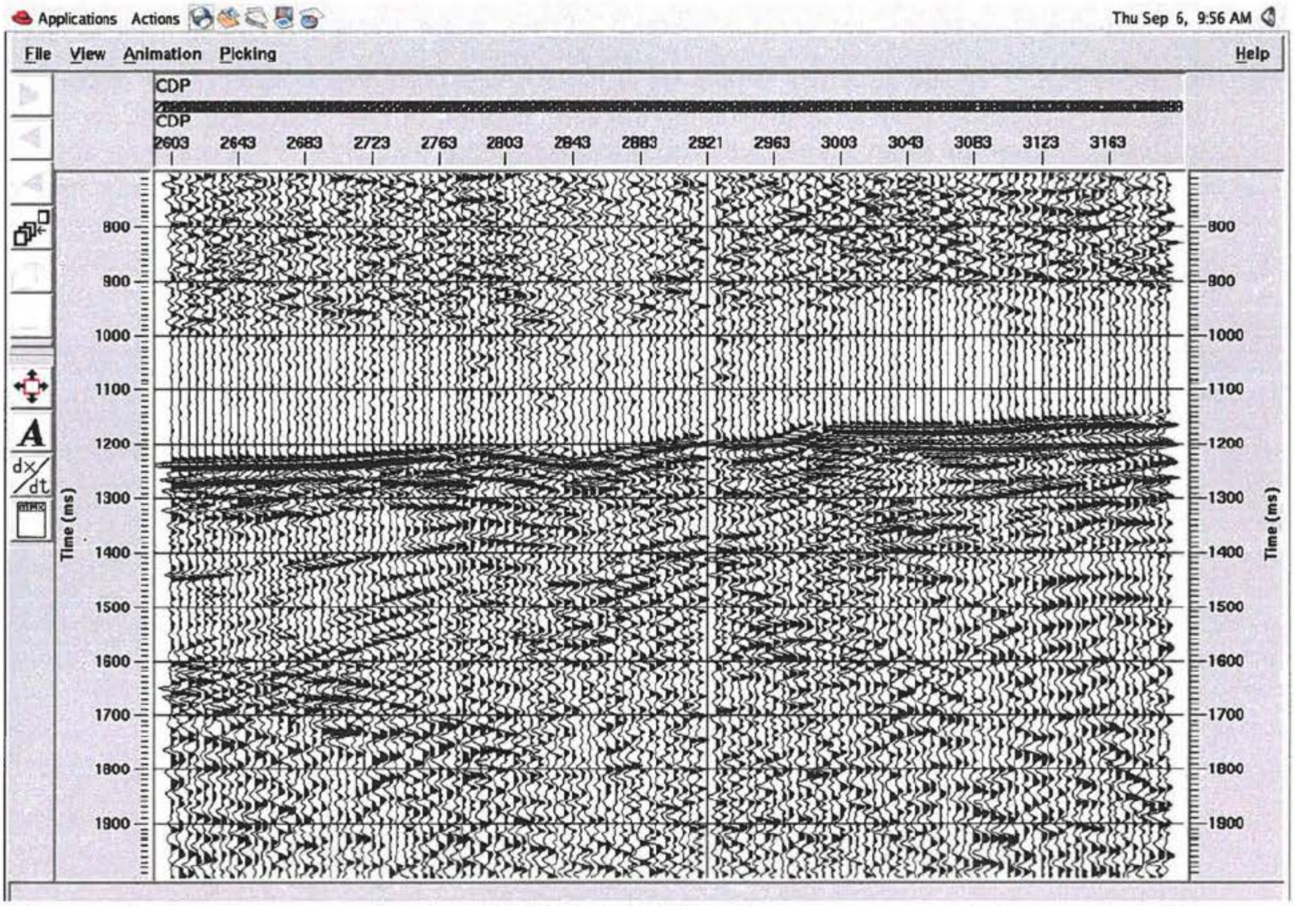


Figure 19. *Previous page: Stack of LOMROG07-3 with no streamer statics applied. This page: Same stack as on opposite page but with streamer statics applied.*

7.7 Band Pass Filter

The band pass filter (Fig. 20) is applied to the data post-stack and has the dual purpose of eliminating the high amplitude low frequency noise from the vessel and enhancing the primary data. A time and space variant minimum phase filter was chosen with three different low-cuts: 20-30-80-100 Hz; 15-25-80-100 Hz and 10-20-80-100 Hz.

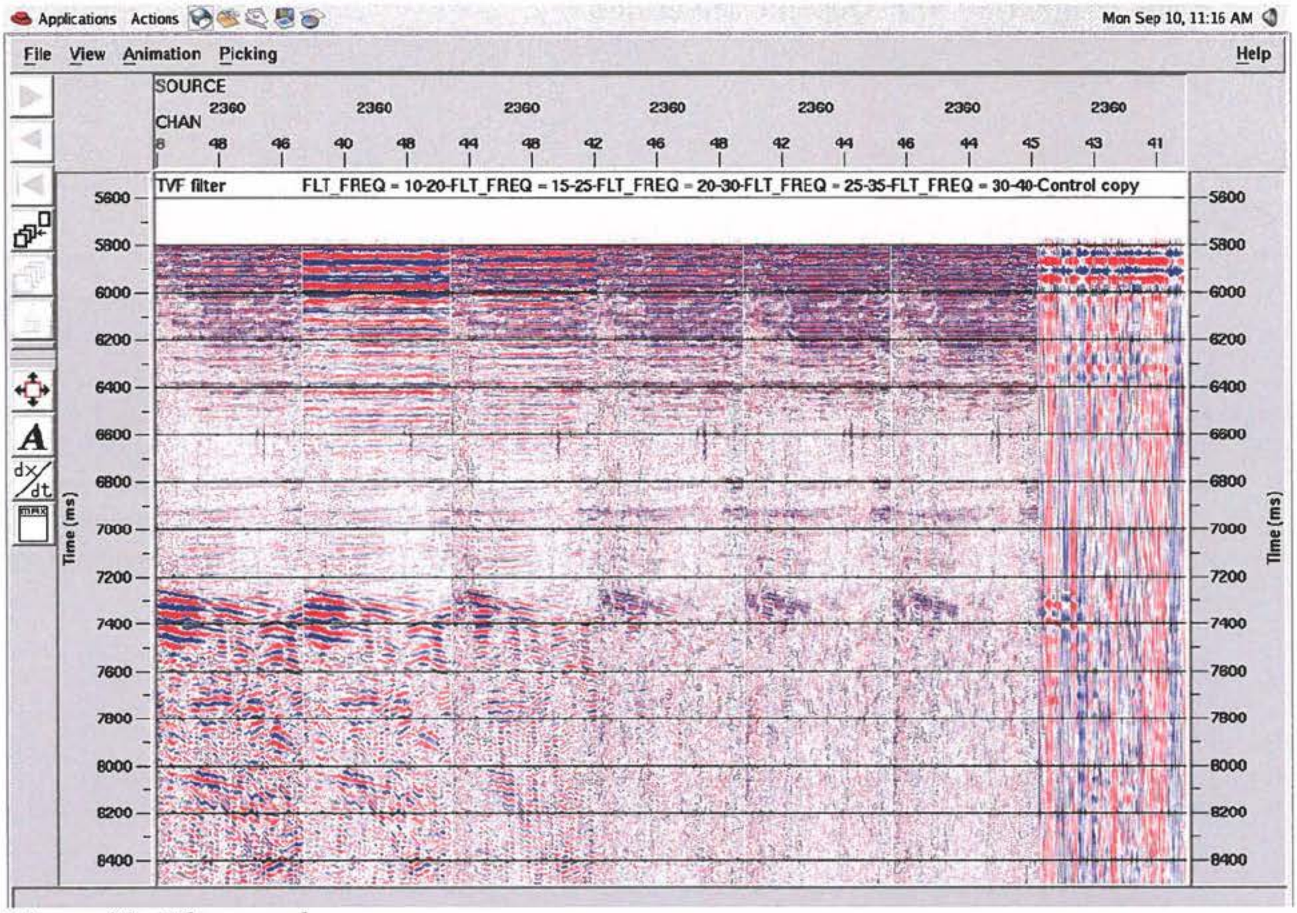


Figure 20. *Filter panels*

7.8 Velocities

The maximum offset of 344 m means that the differential moveout on the traces is very small. Even the seabed reflection has a moveout of only 5 ms for LOMROG07-1 in the abyssal plain and 30 ms for the shallower seabed on the Lomonosov Ridge. Thus virtually no velocity information is contained in the data. For the stacks made during on-board processing "common-sense" velocities were chosen. For final stacking and particularly for migration and depth conversion the velocities from the sonobuoys will be used and correlated along picked horizons on the data. For details on the sonobuoys see chapter 8.

7.9 Stacking

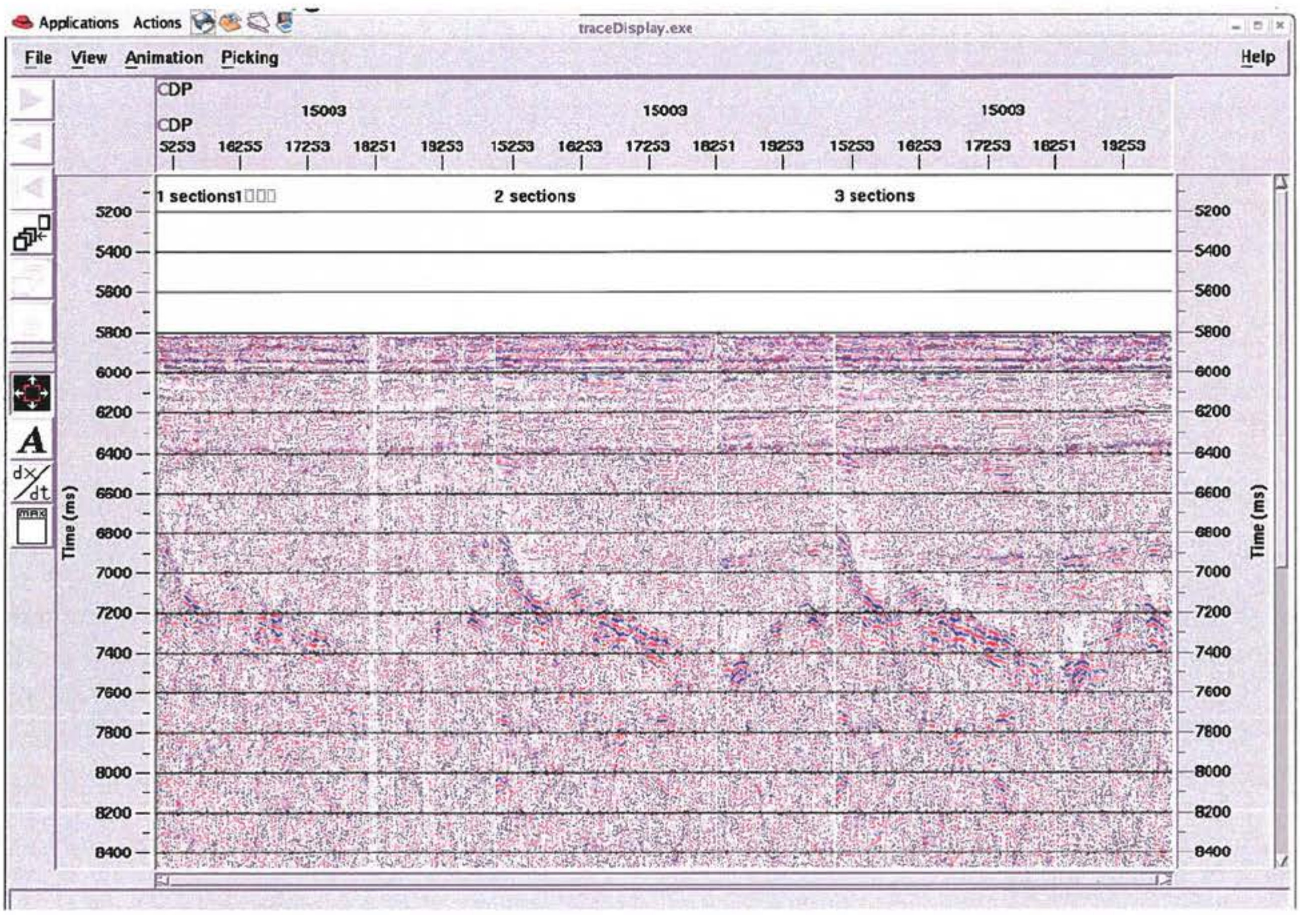
The data were stacked following trace editing, streamer static correction (only LOMROG07-3), shot-mix and NMO correction. After stack the data were band pass filtered and an automatic gain control (AGC) with a window length of 500 ms was applied.

7.10 Migration and Depth Conversion

Not attempted on board.

7.11 Tests for Acquisition Parameters

When acquiring data in such a hazardous environment as the pack ice with ice concentrations of 10/10, the seismic equipment towed behind *Oden* is prone to be damaged. The streamer length used for LOMROG07-1 and 3 was six sections of 50 m length each; in total 300 m active streamer. Based on the data acquired with this streamer it was attempted to evaluate how the data quality is affected by the streamer length. In Fig. 21 a section of LOMROG07-1 is stacked using only part of the streamer ranging from one section (1-fold) to all six sections (6-fold). Otherwise processing was identical, although all data had undergone fk-filtering with all six sections. Visual inspection of the test panels suggests that a streamer shortened to four sections will provide data with only slightly reduced quality.



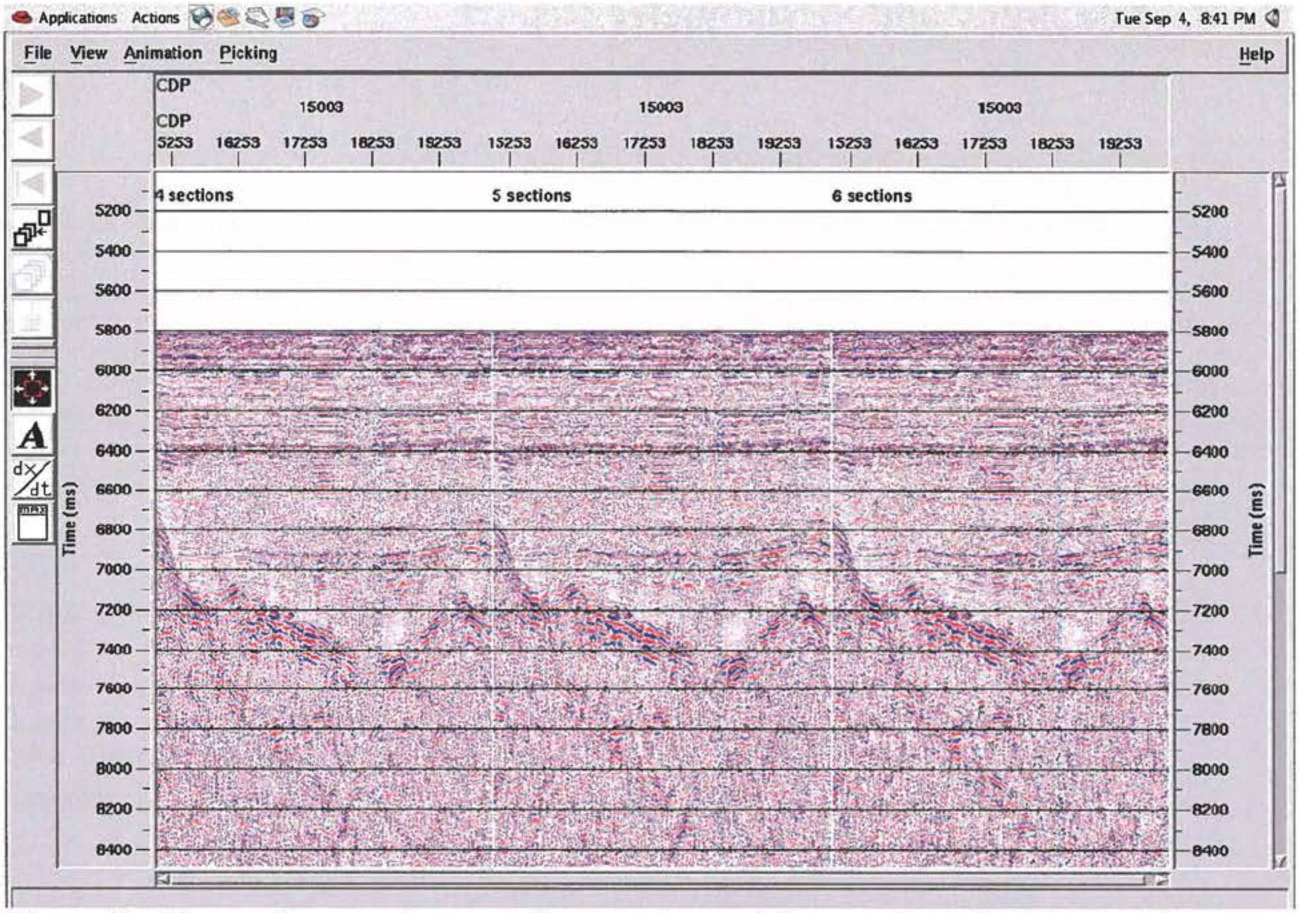


Figure 21. The panel on previous page has one, two and three sections; the top panel four, five and six sections (complete streamer). There are only slight differences in data quality when using four, five or six sections.

7.12 Data Storage

ProMAX archive files (without the seismic data) are stored, as well as the stacks in SEGY format. The original data in SEGD format is stored on tape and on disk.

8. Sonobuoy and Seismometer Report

By Thomas Funck, Geological Survey of Denmark and Greenland

8.1 Technical Description

8.1.1 Seismic Source and Receivers

During the reflection seismic data acquisition of the LOMROG 2007 expedition, a Geometrics streamer with a maximum active length of 300 m was used for recording. A longer streamer was not manageable in the ice-infested Arctic waters and as consequence, velocity information from the sediments are very limited. However, sediment velocities are important for the documentation of the sediment thickness of the extended continental shelf, if the 1-%-sediment-thickness formula (Gardiner line) is to be applied. Therefore, sonobuoys were deployed to record the seismic signals at larger offsets.

Figure 22. *605 cubic inches G-GI gun cluster used for the seismic experiment.*

The sonobuoys recorded the shots from the reflection seismic experiment with a nominal shot spacing of 25 m. The seismic source was a G-GI gun cluster consisting of two G guns with a volume of 250 cubic inches each and a GI-gun with a volume of 105 cubic inches (Fig. 22). The total volume of the array was 605 cubic inches (9.9 L); the air pressure was 3000 psi (200 bar). Nominal towing depth of the gun system was 20 m.

Figure 23. *Sonobuoy type AN/SSQ-53D(2) from ULTRA Electronics.*

The sonobuoys were deployed either from the afterdeck of *Oden* or from the ship's helicopter. A total of 17 sonobuoys of the type AN/SSQ-53D(2) from ULTRA Electronics were available for the experiment (Fig. 23, see appendix 4). Seven of the sonobuoys were left from a previous experiment in Labrador Sea in 2006; ten instruments were purchased for the LOMROG expedition. After deployment, the signals of the sonobuoys were received by one of two radios (Winradio WR-2902e, Fig. 24, see appendix 4) that were connected to an antenna (Moonraker MD HB-G3/HS, see appendix 4) mounted on the railing above the bridge at a height of 25.3 m (Fig. 25). A spare antenna (Moonraker type MD-HS) was not used during the expedition. Between the Winradio and the antenna, a 50-m-long antenna cable, an amplifier and a signal divider were used. Signals from radio 1 were recorded on auxiliary channel 1 of the multichannel acquisition system (Geometrics); radio 2 was recorded on auxiliary channel 2. These auxiliary channels correspond to channels 49 and 50, respectively, in the raw SEGD files of the Geometrics recording system during lines 1 through 3 that were shot with six active streamer segments (corresponding to 48 channels). On line 4, four active streamer segments were used and here auxiliary channels 1 and 2 correspond to channels 33 and 34 in the SEGD files. The sampling rate was 1 ms (1000 Hz). Along MCS lines 3 and 4, sonobuoy data were also recorded on a Taurus seismometer (manufactured by Nanometrics, Fig. 26, see appendix 4) by dividing the signal of the Winradio. Winradio 1 was recorded on channel 1 of the Taurus recorder; Winradio 2 was recorded on channel 2 of the Taurus. The serial number of the Taurus used for recording was 465. The sampling rate was set to the lowest value (2 ms corresponding to 500 Hz). By continuous recording of the data on the Taurus instrument, the record length of the sonobuoy data was no longer controlled by the multichannel system that used record lengths as low as 8.5 s, which is insufficient for far-offset observations.

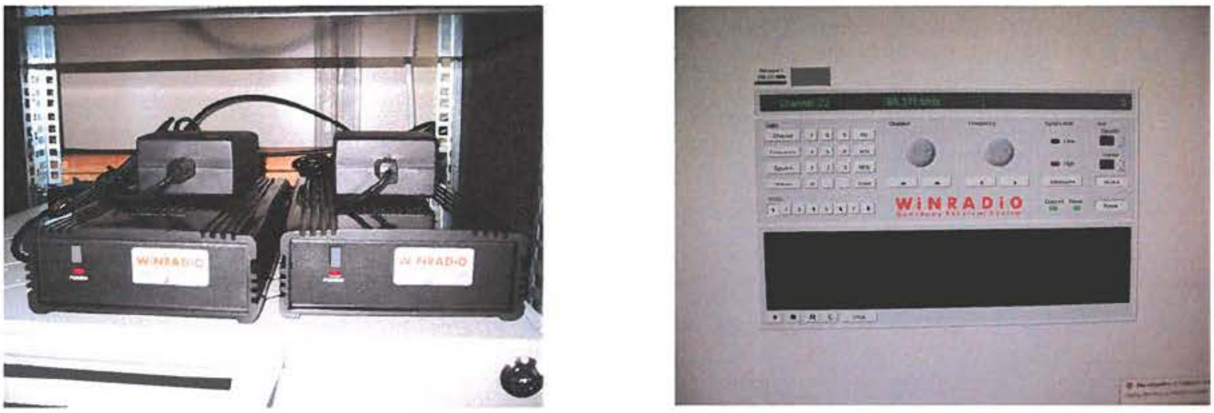


Figure 24. *Sonobuoy receiving system Winradio WR-2902e. Two receivers were used (left) together with application software (right).*

Figure 25. *VHF base station antenna MD HB-G3/HS mounted on top of the bridge of Oden on the port side. The antenna was covered with a pipe.*

Figure 26. *Taurus seismometer in the recording container on the 4th deck of Oden (left) and a close-up of the recorder (right).*

A second type of instruments brought to the ship for the wide-angle reflection and refraction seismic data acquisition, are Taurus seismometers. The seismometers were prepared for the use with either a vertical geophone as sensor (L4 1-Hz geophone, see appendix H) or with a hydrophone (Teledyne Benthos AQ-2000, see appendices F and G) deployed at a depth of 30 m. However, the Taurus seismometers were not deployed on the ice due to unreliable helicopter flying weather.

8.1.2 Container and Laboratory Setup on *Oden*

Several laboratory and storage spaces were used for the sonobuoy and seismometer operation. On the port side of deck 4, the seismic registration container was located. Here the navigation software (NaviPac) and multichannel registration software and equipment (Geometrics) were installed. Also the two Winradios for the sonobuoy reception were in this container, in addition to the Taurus recorder for which a GPS antenna cable was run to the outside through a cable-funnel in the container. A laboratory container on the ship's front on the 4th deck (second container on the port side, container number 10) was used for the preparation of the Taurus instruments as well as for data processing and analysis, using a UNIX workstation (model Sun Blade 150). Sonobuoys were stored in a container on the afterdeck (second container level at the far end of the starboard side).

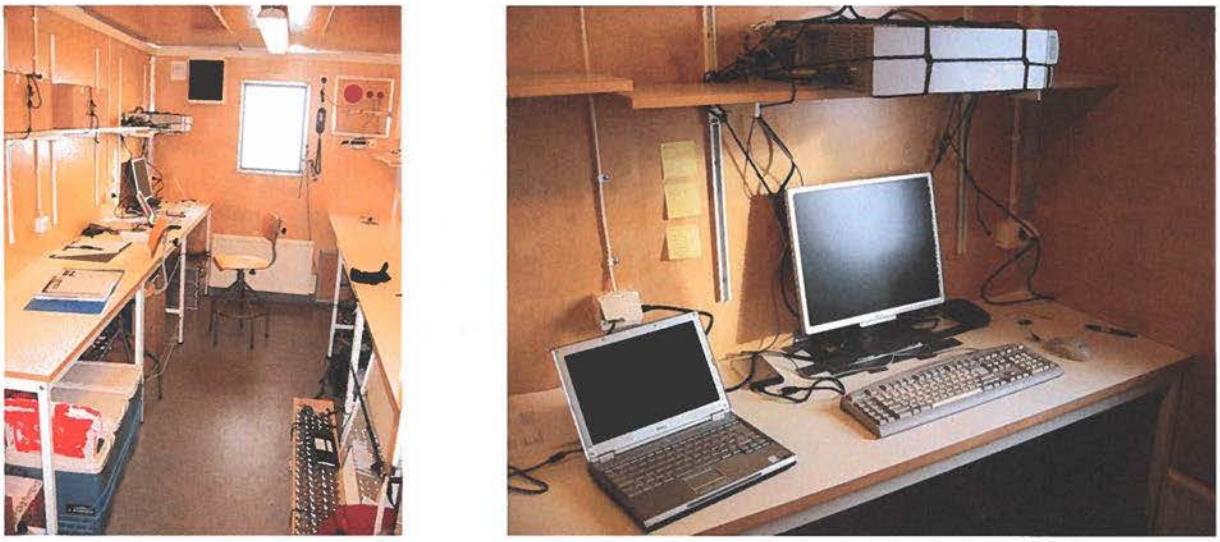


Figure 27. *Setup of the laboratory container on the fourth deck used for the preparation of seismometers and for data processing and analysis.*

8.1.3 Line Locations and Operation

On lines 1 and 3 a total of ten sonobuoys were deployed (see Table 7). Eight of the buoys were deployed from the lowermost afterdeck (Fig. 28) into the wash of the ship as this was the only available ice-free area. Deployment from the afterdeck had a high failure rate (50 %), because it takes about a minute for the buoy to come back to the surface after deployment. Often ice has moved in by then preventing the buoy from surfacing; or the buoys were crushed by ice blocks after surfacing. In addition, the proximity of many tilted ice blocks to the sonobuoy reduced the range of the radio signal. In the best case (buoy 1A-2), signals were recorded up to distances of 9 to 10 km.

During seismic line 3, two sonobuoys were deployed by helicopter. The plan was to deploy the buoys some 20 km ahead of the ship in open water. There were several reasons for the deployment by helicopter. First, the failure rate of a deployment in open water should be very much reduced. Second, the range of the radio signal is expected to be larger and, third, it should be tested if the airgun signals are strong enough to propagate for 20 km.

The strategy for the deployment by helicopter was to fly a course of 190° corresponding to the general ship track and look for an open water pool some 20 km away from the vessel. At that range, a pool with a diameter of ~200 m was found. The helicopter was flying at the centre of the pool at an altitude of 5 m and the sonobuoys were dropped in the water after the rear door was opened. Prior to deployment, the parachute of the sonobuoy was removed because the pilots did not feel comfortable with it and were concerned that the parachute might be caught by the rotor blades. Both sonobuoys did not surface after deployment. There is some normal failure rate associated with sonobuoy deployments but it could also be that the removal of the parachute has caused the malfunctioning. For this reason, no more helicopter deployments were attempted. The helicopter deployment was documented by Kenneth Sorento from the film team. Funny enough, the sonobuoys did not surface after the deployment, but a seal was showing up in the open water pool instead.

On line 4 in NE Greenland, a total of seven sonobuoys were deployed. Here the buoys were deployed from the port side of the afterdeck, as ice conditions were more favourable. The first five sonobuoy positions were in ice-free water and the sixth buoy was deployed in water were the first scattered ice floes occurred. At the position of the last sonobuoy, the ship was moving through denser ice and here the deployment was postponed until a small gap in the ice was reached. Due to the shape of the hull of *Oden*, it is difficult to predict the ice situation from the after deck. For the last sonobuoy, ice observations were communicated from the bridge to the afterdeck to determine a good location for the deployment. Nevertheless, the last sonobuoy did not surface, while the first six buoys on line 4 operated normally. Sonobuoy deployment positions and shot locations are shown in Figs. 29 through 31.

Figure 28. *Sonobuoy deployment from the afterdeck of Oden.*

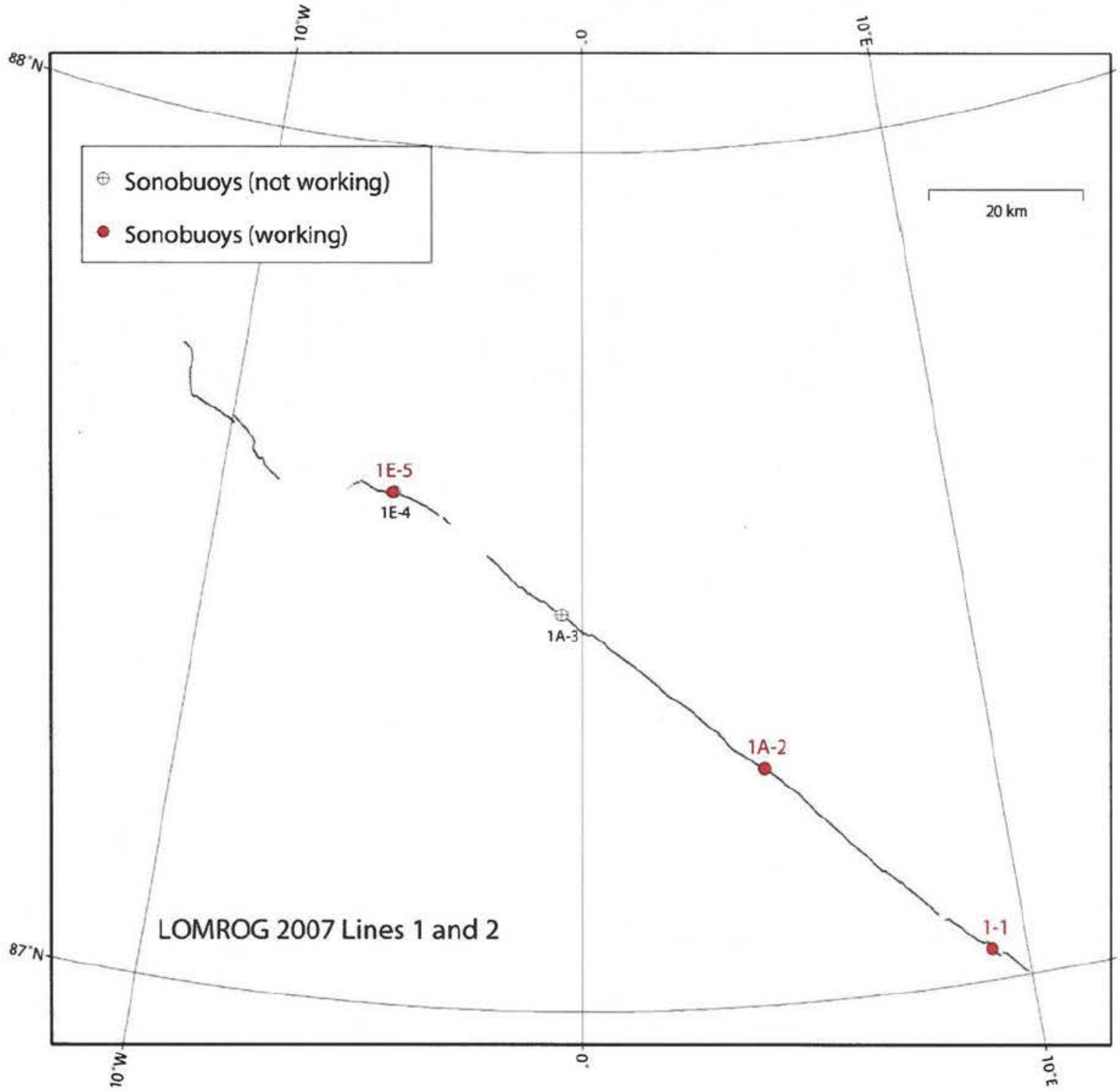


Figure 29. *Location map of LOMROG 2007 reflection seismic lines 1 and 2 (blue line) shown together with sonobuoy deployment positions (circles).*

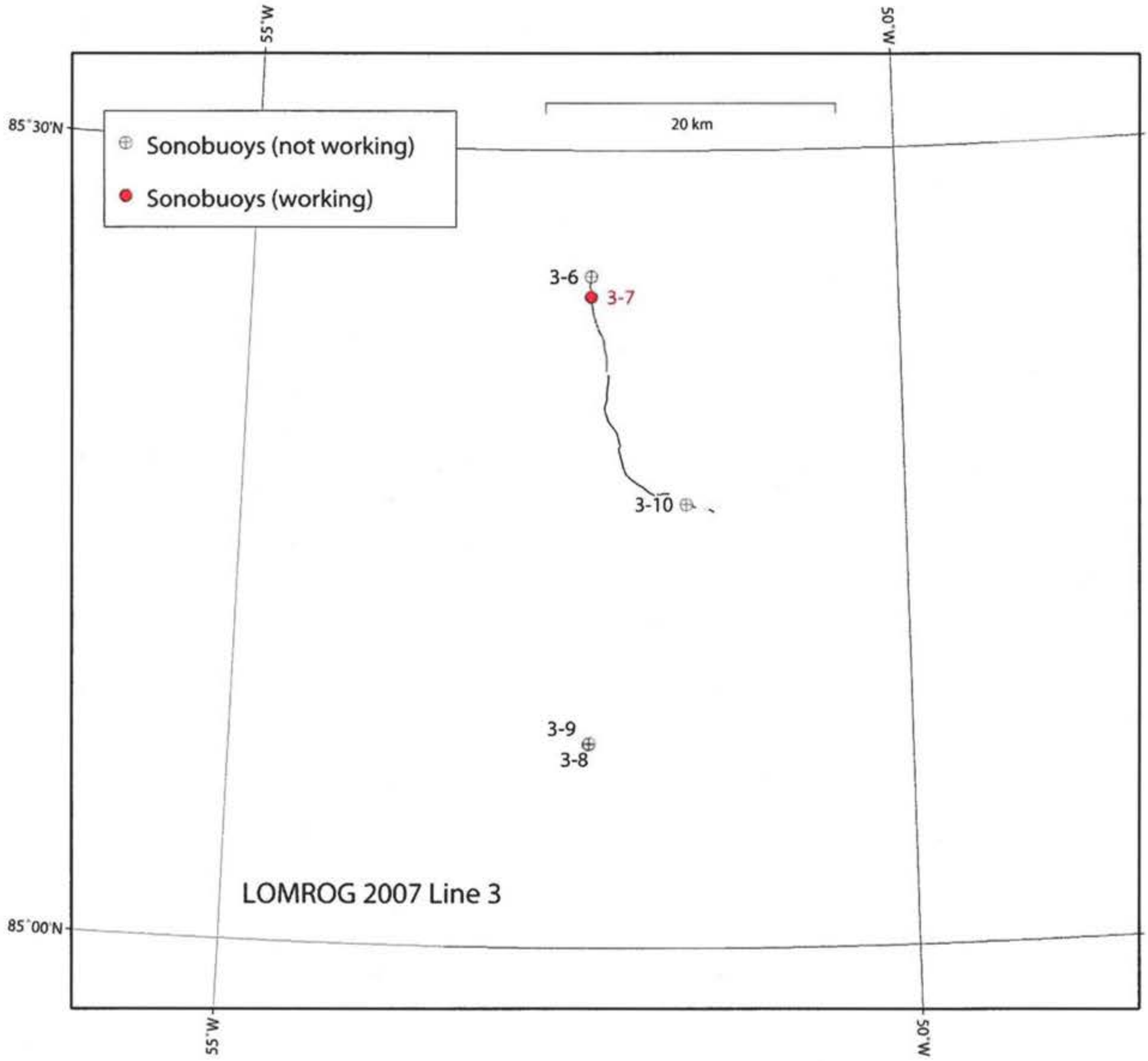


Figure 30. *Location map of LOMROG 2007 reflection seismic line 3 (blue line) shown together with sonobuoy deployment positions (circles).*

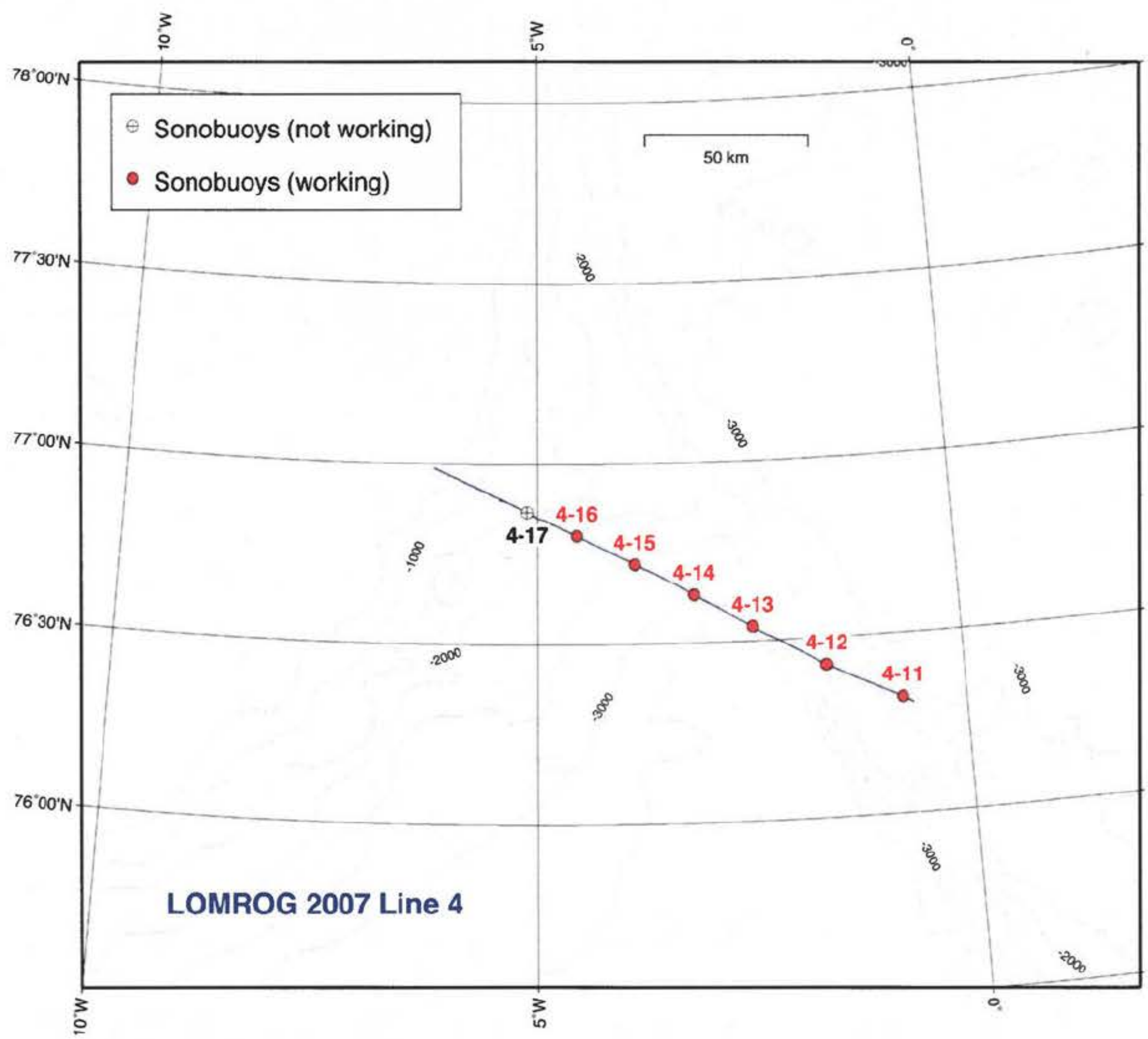


Figure 31. *Location map of LOMROG 2007 reflection seismic line 4 (blue line) shown together with sonobuoy deployment positions (circles). Contour interval of the bathymetry (solid lines) is 500 m.*

Table 7. *Sonobuoy deployments.*

Deployed on MCS line	Sonobuoy station name	Depth setting	Operating life	Channel number	Recorded on auxiliary channel	Recorded on Taurus component/ channel	Day of deployment (Julian Day)	Time of deployment (UTC)	Longitude	Latitude	Remarks
1	1-1	D1=30 m	8 hours	76	1 and 2	-	19 AUG 2007 (JD 231)	03:05:30	9°12.238'E	87°02.197'N	First few minutes not recorded (wrong receiver channel).
1A	1A-2	D1=30 m	8 hours	76	1 and 2	-	19 AUG 2007 (JD 231)	10:14:25	4°26.768'E	87°16.524'N	Receiver shut-down at 12:48 UTC.
1A	1A-3	D1=30 m	8 hours	52	1 and 2	-	19 AUG 2007 (JD 231)	16:05:23	0°33.889'W	87°27.698'N	No signal.
1E	1E-4	D1=30 m	8 hours	52	1 and 2	-	19 AUG 2007 (JD 231)	22:12:30	5°13.885'W	87°35.720'N	Deployment position taken some 200-300 m too late. Sonobuoy did not come to surface.
1E	1E-5	D1=30 m	8 hours	52	1 and 2	-	19 AUG 2007 (JD 231)	22:31:15	5°17.261'W	87°35.671'N	
3	3-6	D1=30 m	8 hours	52	1	1	26 AUG 2007 (JD 238)	15:40:20	52°23.150'W	85°25.267'N	Did not surface after deployment.
3	3-7	D1=30 m	8 hours	22	2	2	26 AUG 2007 (JD 238)	16:04:55	52°23.100'W	85°24.492'N	Position taken some 30 seconds after deployment.
3	3-8	D1=30 m	8 hours	52	1	1	26 AUG 2007 (JD 238)	20:52:00	52°22.704'W	85°07.615'N	Deployed by helicopter after removal of parachute. Did not surface.
3	3-9	D1=30 m	8 hours	22	2	2	26 AUG 2007 (JD 238)	20:59:00	52°22.592'N	85°07.666'N	Deployed by helicopter after removal of parachute. Did not surface.

3	3-10	Dl=30 m	8 hours	52	1	1	27 AUG 2007 (JD 239)	00:51:35	51°39.500'W	85°16.690'N	Did not surface.
4	4-11	Dl=30 m	8 hours	87	1	1	13 SEPT 2007 (JD 256)	01:00:00	0°44.382'W	76°19.406'N	Ice-free water.
4	4-12	Dl=30 m	8 hours	99	2	2	13 SEPT 2007 (JD 256)	04:02:15	1°36.447'W	76°25.442'N	Ice-free water.
4	4-13	Dl=30 m	8 hours	87	1	1	13 SEPT 2007 (JD 256)	07:08:15	2°27.170'W	76°32.380'N	Ice-free water.
4	4-14	Dl=30 m	8 hours	99	2	2	13 SEPT 2007 (JD 256)	09:38:30	3°08.113'W	76°37.972'N	Ice-free water.
4	4-15	Dl=30 m	8 hours	87	1	1	13 SEPT 2007 (JD 256)	12:11:00	3°49.806'W	76°43.276'N	Ice-free water. Position recorded ~20 s after deployment.
4	4-16	Dl=30 m	8 hours	99	1 and 2	1 and 2	13 SEPT 2007 (JD 256)	14:34:50	4°31.300'W	76°48.100'N	Light ice.
4A	4-17	Dl=30 m	8 hours	87	1	1	13 SEPT 2007 (JD 256)	18:47:25	5°07.352'W	76°52.017'N	Did not surface. 3/10 to 5/10 ice.

8.2 Data Retrieval and Processing

8.2.1 Navigation

Shot times and positions were extracted from the headers in the reflection seismic data (one SEGD file for each shot) and are stored in the files *lomrog2007-seis[line#].nav*. This extraction was done by Trine Dahl-Jensen, who used ProMAX software for this purpose, which was installed on her laptop computer on a Linux boot partition. Positions in the header were originally obtained from the NaviPac system and are corrected for the offset between the gun array and the GPS antenna. Positions are given as x and y values (Easting and Northing in meters) in the Universal Polar Stereographic (UPS) projection with the following projection parameters:

- Reference longitude: 25° W
- Standard parallel: 81° 07' N
- Reference ellipsoid: WGS 84
- False Northing: 2.000.000 m (corresponding to the y value at the North Pole)
- False Easting: 2.000.000 m (corresponding to the x value at the North Pole)

For accuracy reasons, the *lomrog2007-seis[line#].nav* files use other values as false northing and easting, thus avoiding values > 1.000.000 m. For line 1, false easting and northing were 0 m and 1.000.000 m, respectively. On line 3, both the false easting and northing were 1.000.000 m. On line 4, the false easting was 0 m, while the false northing was 2.000.000 m. The UPS coordinates were later transformed to geographical coordinates (longitude and latitude) employing the process *mapproject* in the Generic Mapping Tools (GMT) software.

On line 4, the navigation and shot time data extracted from the SEGD files were found to be erroneous for many shots. Often the data were completely missing or the header information from a later shot was written into the SEGD file. After a reboot of the Geometrics computer, data were written correctly for lines 4A and 4B. The reboot was not carried out to solve the problems with the headers (this was first noticed later), but because the computer was slow. It is unknown what caused the poor performance of the computer, but a problem with the Geometrics software is considered the most likely reason. Due to the erroneous data in the SEGD headers, manual editing was necessary to associate the saved positions and shot times with the correct shot number. For shots with no information, interpolation was carried out. The validity of this approach was confirmed by the visual inspection of the sonobuoy record sections.

The shot time in the SEGD headers is only an approximation with the day, hour, minute and second being correct. To obtain the fractions of the second, a PPS pulse was recorded on auxiliary channel 3 (corresponding to channel 51 in the SEGD files of lines 1 and 3, and channel 35 on line 4). An auto-picking routine in ProMAX was used to determine the delay of the first second pulse for each shot, from which the exact start time of each record/shot could be calculated. More details on the SEGD headers and the calculation of the positions and times can be found in chapter 7.

The water depths in the *lomrog2007-seis[line#].nav* files were provided from the ship's multibeam system (central beam) using a water-velocity function obtained from CTD measurements that were carried out prior to each seismic line. The values are given in meters below the transducer, which was mounted at a depth of 8.2 m below sea level. Depths in the files are raw values; no editing was applied to remove erroneous values, which were numerous due to the wash with ice and bubbles from the Russian lead ice-breaker *50 Let Pobedy*.

Deployment positions of most of the sonobuoys (Table 7) were obtained from a hand-held GPS unit (model GARMIN geko 201) at the afterdeck, normally within five seconds after the buoy was thrown into the water. For sonobuoys 4-13 and 4-16, the exact deployment time was noted by the watch keeper in the registration container, together with the position.

8.2.2 Data Retrieval

Raw SEGD files of all shots were transferred from the Geometrics registration computer to the workstation in the processing container, where the processing and further analysis of the sonobuoy data were carried out. Filenames are *[shotnumber].SEGD*, e.g. *631.SEGD*

Data from the Taurus instruments were downloaded to a PC using the Ethernet interface of the recorders, which allow access with a web-browser. Data format of the downloaded time series is ASCII. Each file is divided into smaller blocks with an ASCII header that specifies the start time and sampling rate of the following block. The data block is a comma separated list with amplitude values for each sample. File names are

> [Taurus serial number]_taurus_[Taurus serial number][year][month][day]_[time in hhmmss]ch[recording channel].txt
>
> for example *465_taurus_0465_20070826_150000ch1.txt*

The compact flash cards that were used for recording in the Taurus were also stored as additional backup.

8.2.3 Data Processing

Sonobuoy data recorded on the Geometrics system were converted from SEGD to SEGY format using the software Seismic Unix installed on the SUN workstation. Data recorded on the Taurus seismometers were converted from ASCII to SEGY format by UNIX scripts and FORTRAN programs that extracted the appropriate time windows using the shot times in the navigation file. Shot positions, receiver position (=sonobuoy deployment position), water depth, gun depth, shot time, and offset were written into the header. The offset was calculated from the shot and receiver positions, no drift corrections were applied initially. These SEGY files are located in the directory *data/lomrog/sonobuoys/segy-raw* and are named *sono[sonobuoy number]-[aux/taurus][channel 1/2].sgy*. Data recorded on the Geometrics system are named *aux(1/2)* with the number indicating the auxiliary channel; file names with *taurus(1/2)* identify the recording channel of the Taurus system.

Sonobuoy data on line 1 were recorded both on Winradio 1 and 2 and it was found that the record sections appeared slightly better on Winradio 1. On line 4, the sonobuoys were recorded alternately on radio 1 and 2. The signal strength on radio 2 appeared to be reduced compared to radio 1 and it was decided to perform another test with the signals recorded on both radio 1 and 2 (sonobuoy 4-16). A significant difference was noticed on the two record sections. The signals on radio 2 were weaker and in particular refracted energy was much more subdued compared to radio 1.

No significant difference in the noise level was found for the sonobuoys recorded both on the Winradio and the Taurus. However, slight variations or scatter of the arrival times can be seen on the Taurus data that is not visible on the Winradio data. This is attributed to some uncertainty in the picking routine used to determine the exact shot time. This scatter can probably be removed or at lest reduced when the PPS pulse on auxiliary trace 3 is picked manually. However, if there is a redundant recording from the Geometrics system with sufficient record length, this exercise is not necessary.

While the sonobuoys transmitted signals back to the ship, they were drifting in the ice and the water. Since the sonobuoys are not equipped with a GPS or other navigation systems, their exact position is unknown. However, from the arrival time of the direct water wave, the distance between the shot and sonobuoy can be calculated. For this purpose, travel times for all direct arrivals were picked by means of the program *zplot* (written by Collin Zelt). The distance to the sonobuoy was then calculated by using a water velocity of 1443 m/s (line 1), 1437 m/s (line 3), or 1445 m/s (line 4). These velocities were found in the top water layer using CTD measurements. Not on all traces the direct wave could be picked. For these shots, a linear interpolation or extrapolation was carried out. These new offsets were then written into the SEGY headers and the SEGY files are stored in the directory *data/lomrog/sonobuoys/segy-driftcorr* using the same file nomenclature as for the raw SEGY files.

Plots of the sonobuoy data are shown in appendix A. The record sections are plotted versus offset. Data were debiassed, followed by a band pass filter (5 to 24 Hz). AGC scaling with a window length of 2 seconds was applied to lines 1 and 3, for line 4 the traces were scaled by range. On line 4, travel times are reduced with a reduction velocity of 4.5 km/s.

8.3 Recommendations and Conclusions

8.3.1 Seismometers and Satellite Trackers

The sonobuoy program was originally thought to be complemented by the deployment of seismometers along the seismic lines. For this purpose, four Taurus seismometers were borrowed from the Geological Survey of Canada (GSC); the instrument type and packaging (within a cooler box) is identical to the LORITA experiment in 2006 (a joint GSC and GEUS program north of Ellesmere Island and Greenland). Two types of sensors were available for the instruments, an L4 1-Hz vertical geophone (see appendix H) and a Teledyne/Benthos AQ-2000 hydrophone attached to a 30-m-long cable (see appendices F and G). In addition, three CarteNav ETS-1500 ice floe trackers were borrowed from the GSC, which report their GPS position to a web server every hour.

None of the seismometers were deployed during the program and the main reason for this was the marginal flying weather. Although in many occasions the seismometers could have been flown away from the ship for 20 nm to record wide-angle reflections and refractions, there was the risk of weather deterioration during the shooting, which could have prevented a recovery of the instruments. Between deployment and recovery could easily go 12 hours and the weather was essentially unpredictable. There was almost a constant cloud cover, often with mist and fog or light snow fall. Often there was the danger of ice-formation on the helicopter's rotor blades, related to the moist air and the temperatures below or close to the freezing point.

The satellite trackers were meant to aid the recovery of the seismometers that would drift with the ice during the shooting. On board *Oden*, there was no internet connection to retrieve the tracker data directly from the web site. Therefore, GEUS asked CarteNav to filter the tracker data and send an email to the ship to avoid unnecessary transmission delays. This solution was not in place until the start of the cruise and therefore a backup plan was put into place, in which people in the office at GEUS would download the tracker data from the web and send the information via email to the vessel. This was not really tested but could have meant substantial delays in receiving the information on the boat, in particular if needed at weekends or at night. If this system is used again, it should be made sure that the data will be emailed directly from CarteNav, or alternatively, that an internet connection is provided on the ship.

8.3.2 Sonobuoy Recording

The recording of the sonobuoy data on the auxiliary channels of the seismic acquisition system has the disadvantage that the recording length is tied to the one used for the reflection seismic recording. During the expedition, the record length was gradually decreased from 11 to 9.5 or 8.5 s to allow the vessel to manoeuvre at higher speeds than the nominal 4 knots, in order to break the ice more efficiently and to follow the Russian lead icebreaker. With the reduced recording length, a shot spacing of 25 m could be maintained, which was important for the fold of the reflection seismic data. However, record lengths of only 8.5 s are not sufficient for the sonobuoys when larger offsets are considered. For example, at 8.5 s the direct water wave will not be recorded for offsets >12 km, which is essential for the calculation of the drift correction.

To address this problem, data from the Winradio were also recorded on a Taurus seismometer that allows for continuous recording. For future expeditions, this possibility for continuous recording should be kept. This will guarantee that no seismic information gets lost.

During the experiment it was noticed that the sensitivity of the second Winradio was reduced compared to the first receiver. It should be tried to track down the reason for this problem and it is recommended to bring a third Winradio as spare on future expeditions. The simultaneous connection of two Winradios with different frequencies to the VHF antenna may also cause some interference.

8.3.3 Sonobuoy Operation

The success rate of the sonobuoys on lines 1 and 3 with 10/10 ice coverage was only 40 %. Some of the reasons for this are discussed below, but it emphasizes that sufficient spare sonobuoys should be brought on an expedition to ice-infested Arctic waters.

The main reason for the failure of the sonobuoys was probably that the ice closed behind the ship in the minute it takes for the sonobuoy to descend to the operating depth of 30 m and to resurface afterwards. Heavy wash from the ship's propellers may accelerate the movement of the sonobuoy away from the ship and under the ice. Even when the buoy surfaces again, it will still be in the area where individual ice blocks are exposed to substantial movements before the wash and ice eventually calm down some 200 m behind the ship. During this phase, the sonobuoy is exposed to the risk of being crushed in the ice.

To reduce these deployment risks, it was attempted to find some open water and deploy two buoys by helicopter from an altitude of 5 m. Both buoys did not surface and one possible reason could be the removal of the parachutes prior to the deployment. The deployment altitude would not really require the use of a parachute and from the manual it was not obvious that the parachute has an essential function once the buoy has plunged into the ocean. This is something that should be discussed with the manufacturer of the buoys since helicopter deployment still appears to be the best option in thick ice with 10/10 coverage, supposed that some smaller open water areas can be found close to the ship's track.

According to the manual, sonobuoys should be deployed into sea water with a temperature of 0°C to +35°C. In the study area north of Greenland, the water temperature was generally between -2°C and -1°C. Hence, temperature effects may have contributed to the failure rate.

Sonobuoys were shipped to *Oden* in their storage containers without the shipping pallet. The manufacturer recommends to retain the sonobuoy in the shipping pallet until it is needed in order to optimize the reliability. In an effort to reduce the failure rate, it is recommended to bring the pallet on the ship during future expeditions and to place it somewhere more accessible. Next to the reliability issue, this will substantially decrease the time a second buoy can be launched in case that the first one fails.

In contrast to marine seismic data acquisition in ice-free waters, it is difficult to plan exact deployment positions in ice-infested waters. Often ice conditions behind the ship prohibited a successful launch of the buoys and instead there was focus on finding the most promising ice and wash conditions. However, in areas with less severe ice conditions, one sonobuoy should always be on standby to be deployed when the seismic recording system (the brute stack monitor) indicates basement lows with thick sediments. This way it is ensured that also velocity information from deeper sediment layers is obtained.

On line 4, the first five buoys were deployed in ice-free water with a success rate of 100 %. However, only one of two sonobuoys were successfully launched at the western end of the line where the ice cover was up to 5/10.

8.3.4 Range of Sonobuoy Radio Signal

The range of the VHF signals of the sonobuoy is determined by the line of sight. With the height of the transmitting antenna being fixed just above sea level, the radio range can only be increased by raising the height of the receiving antenna. In ice-free waters, the antenna height of 25 m should have resulted in ranges of 21 km (using the radio range calculator on http://www.naval.com/sight/index.htm). On line 4, ranges of up to 22 km were observed, whereas the ice between the buoy and the ship's antenna on lines 1 and 3 decreased this range to 9-10 km. As there is a limit up to which level the antenna can be raised on the ship, intermittent ice-free waters should be used for sonobuoy deployment to extend the range of the radio signals provided that such waters exist. Since ice is moving, the strength of the signal received from the buoy can be variable. It happened that the signal essentially disappeared for some time just to come back a few shots later. Therefore, some extra time allowance should be made before ending the recording of a buoy.

8.3.5 Range of Seismic Source

The quality of the sonobuoy records is influenced by the receiving system (antenna, cables, receiver), by the maximum range of the signals (line of sight), and by possible obstacles (ice) between the buoy and the receiver antenna. In order to get a better estimate of the range of the airgun signal without possible deteriorations by the receiving system and other limitations inherent to the HF transmission, it was planned to deploy a seismometer equipped with a hydrophone and geophone at a distance of 20 nm from the ship (corresponding to the helicopter range). However, the weather did not allow for a helicopter deployment at that range. Instead, only sonobuoy recordings can be used to deduce the range of the seismic signal. The theoretical maximum range of the sonobuoy signals with the given antenna height on the ship is 21 km.

In the ice-free water encountered along portions of line 4, seismic energy was transmitted back to the vessel for ranges up to 21-22 km. However, this is only true for the more high-frequent portions of the signal as the direct wave, and reflections from the seafloor. Seismic energy from deeper levels (e.g., crustal refractions and reflections) that has a higher content in low frequencies is substantially attenuated for offsets > 13 km, although sonobuoy 4-13 allows for some correlation up to 18 km. Unless the amplitude decrease of the refractions at around 13 km is related to the velocity-depth distribution in the basement, this could indicate that the maximum range of the airgun cluster lies somewhere between 13 and 18 km.

Individual chambers of the G-GI gun cluster have a maximum volume of 250 cubic-inches, which is an excellent size for the seismic mapping of the sediments down to basement. This volume is also sufficient to determine the velocities in the sediments by using the sonobuoy records. Hence, the objectives of this seismic experiment are met, which were to determine the sediment thickness. However, in other types of experiments in which also the crustal velocity structure is of interest (e.g., to check for continuation of basement structures), more low-frequent sources are required. It might be worthwhile to test a gun with a higher chamber volume that generates a more low-frequent signal. An initial test could consist of a single gun with a volume around 600 cubic inches in one chamber rather than distributed over three chambers as in the G-GI gun cluster used in this experiment. This could be a reasonable compromise between the resolution requirements of the reflection seismic data and the need for slightly larger ranges in the refraction/sonobuoy part of the experiment.

Given the conditions in the Arctic, where plans constantly need to be adapted according to the weather and ice situation, it is important to have some flexibility with the equipment. If there is all of a sudden an opportunity for a seismic line for which the crustal velocity structure does matter, it would be good to have an appropriate seismic source available.

8.4 List of Appendices (Included in Appendix 4)

A Record sections for all sonobuoys

B Technical specifications VHF antenna MD G3

C Technical specifications sonobuoy receiver WR-2902e

D Technical specifications Taurus seismometer from Nanometrics

E Technical specifications sonobuoy AN/SSQ-53D(2) from ULTRA Electronics

F Technical specifications hydrophone Teledyne/Benthos AQ-2000

G Technical drawing of the hydrophone connection to the Taurus recorder

H Technical specifications Mark Products L4 1-Hz vertical geophone

9. Evaluation of the Seismic Equipment and the Setup on *Oden*

By Christian Marcussen and Thomas Vangkilde-Pedersen, Geological Survey of Denmark and Greenland, Per Trinhammer and Holger Lykke-Andersen, Department of Earth Sciences, University of Aarhus

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This chapter summarizes the performance of the seismic equipment during the LOMROG cruise. Furthermore, suggestions for improvements to the seismic equipment and handling of the equipment onboard *Oden* are made.

9.1 NaviPac

Performance:

The navigation software NaviPac did in general perform well, there were, however, some jumps in the event number. Eiva has made a new patch to the programme that solves this problem. However, the file is too large to be e-mailed to *Oden* – and will therefore first be implemented after the cruise.

Suggestions for improvements:

- When operating in ice infested arctic waters one cannot expect to be navigating at constant survey speed. For reflection seismic purposes, where a relatively regular spacing between individual shot points is important, shooting on time cannot be used as the shot point spacing would vary with the survey speed. Neither can one expect to navigate along a straight course or keeping the same azimuth all the time as it at least to some extent will be the local ice-situation that governs the sailed direction. It would therefore be a great advantage if the *NaviPac* software could be upgraded with a facility to calculate distance between events along the actual sailed line rather than projecting distances along the active runline. Otherwise the distance between events will increase when the actual sailed line is deviating from the active runline unless a new runline parallel to the sailed line is selected/generated during acquisition. Furthermore the program should continue shooting, even when the speed is lower than 0.14 kn (drifting).

- Offset coordinates: When the local coordinates for the airgun midpoint and streamer channel 1 offset points were entered into NaviPac the x and y coordinates were given relative to the tow point, but the z coordinate was given relative to the local coordinate system. A value of -20 m was entered because it was planned/expected to tow the guns and streamer at a depth of 20 m. However, the airgun midpoint and streamer channel 1 positions are calculated relative to the tow point and hence the z coordinate assigned to these points was -15.35 m

(-20 m + 4.65 m, with 4.65 m being the z coordinate of the tow point). This has, however no influence on the x and y positions calculated for these offset points. In contrast, if -24.65 m had been entered as the z coordinate relative to the tow point, the airgun midpoint and streamer channel 1 offset point would have been assigned a z coordinate of -20 m in the calculated positions.

- An explanation is needed as to why there is a port error on 9103 (UDP/IP) and 8 (COM). The data are updated every 10 s but there is an error message even when the *navipac.ini* is set to limit (yellow) 20 s and limit (red) to 25 s on port 9103.

- It is unclear why the gyro data have to go through the program Franson GPSgate2.0 to be accepted by NaviPac. Furthermore, it looks like the UDP/IP is more sensitive to "noise" than TCP/IP. A suggestion is to use TPC/IP as an input option.

- "Track plot settings" should be stored in Helmsman's display.

- Data is send to CNT-2 every 1 sec, but should be sent at every event. If set to event the CNT-2 does not get the data at all. Tests regarding this problem have been done on September 7, 2007, and these tests showed that the output "Data to CNT-2" from NaviPac can be set to every event and that the CNT-2 program accepts this input.

- Eiva should explain the difference between COG (or CMG) and the gyro course of the vessel when using the UPS projection. The difference can be eliminated by typing in the actual longitude in "Longitude from pole" during setup, but when sailing in east-west direction in the Arctic the longitude changes rapidly.

- EIVA should implement an option to import other background images than C-map or dxf-files, e.g. a geo-referenced tiff-file or similar.

- When entering offset coordinates relative to a "drag point" like it was done for the airgun and streamer offset points, also z should be entered relative to the coordinates of the drag point, in this case the tow point.

9.2 Geometrics Software CNT-2 Version 4.5

Performance:

One major crash occurred due to software problems during data acquisition. The reason for this crash was most likely because of changing the record length while the program was acquiring data (shooting). This kind of crash can be avoided if parameters are not changed while the program is armed.

There was also a crash while off-line. Geometrics was contacted and they can not give an explanation for this crash. The problem is most likely due to a combination of Microsoft Windows problems and bad network connections. The problem was solved byre- installing the program.

On-line processing worked well but a ProMax processing system (or similar) is needed to do proper processing of the seismic data.

Suggestions for improvements:

- Removal of software bugs.

- How long a cable is allowed with a 100 Mbit repeater? Mark Prouty (Geometrics) has confirmed that 100 m is the maximum length for a 100 Mbit system. The cable that caused problems is an 80 m-long deck cable including two connector junctions, with a 100Mbit repeater. Degradation of the signal probably occurs in the two connectors and this might be the reason why it did not work. Changing to a 10 Mbit repeater solved the problem.

- After setting the *Time Window* in *regedit* to 2000 ms, the serial string from NaviPac seems to be accepted. This is true even when the string is transmitted from NaviPac only once for each event and therefore only one position is stored for each event.

- In a shot gather the first 23 ms look strange. A raw data file (SEG-D) read by ProMAX shows the same. The first 23 samples are zero. Geometrics (Mark Prouty) has confirmed that the programme blanks the first 23 samples (i.e. with a higher sample rate the blank time will be shorter). The reason for blanking the data is due to the step response of the digital filter on the ADC modules, which saturates the display and disturbs the AGC display.

- The depth scan rate depends on the number of sections. With six sections a new value is generated for each 6th shot. It is prefered to have a new depth value for every shot. Furthermore, an option to scan for the depths every 10 to 60 s is desirable in case the shooting stops due to ice, which might cause periods between 10 minutes to a few hours without shooting.

- The maximum depth value for the transducer monitor is 70 m which is not sufficient. The maximum depth for the hydrophones is 200 m (and 300 m survival depth).

- The leakage test on the SPSU is the leakage in the power supply to the ADC modules (measurements are performed between +60 V and -60V). There is also a leakage test in the program, *Testing QC – GeoEel leakage test*. This test is different than the other and is not related to the displayed value on the SPSU. The *GeoEel leakage test* measures the resistance of the hydrophone elements. It is suggested that an audible alarm is added to the leakage lamp on the SPSU, as this is a good indicator for broken sections and the light itself is easily overlooked. It should be possible to switch off the audible alarm.

- Check the navigation file with the positions and file numbers generated by geometrics (a new feature in the program) with NaviPac log files.

- The software should be updated so the display windows show up on the screen as they were organized in the previous session. In other words the layout of the display windows should be stored in an ini-file.

9.3 Gun controller

Performance:

The program had a bug resulting in the GI gun not being synchronized correctly. This had an influence on the P/B ratio that was slightly lower than expected. Nevertheless, the array has performed as a cluster with a P/B ratio better than 25.

Suggestions for improvements:

- An extra controller should be brought along for a new Arctic survey.

- The gun depth monitoring has to be scanned for every 10 s. Furthermore the maximum depth should be 50 m and not 30 m as now. There are a lot of "invalid" depth observations; the reason for this has to be investigated. One of the reasons could be that the monitor is placed too close to the exhaust port of the gun. Macha International Inc. should confirm how close to the gun array the depth transducer can be installed.

- An audible alarm if the gun depth is above a certain level would be nice. Macha International Inc. has to be asked to make a new version of the program that has this option.

- The depth data are stored in a log file. It is difficult to get those data out of the PC as the only removable storage device is a 3.5" floppy disk. The mother board is a 486 that does not support USB. Installation of a network card with RJ45 connector would solve this problem. There is already a BNC network card installed but it does not fit into the local network.

- Delay of 16 ms (12 ms) according to AP (aim point) could be due to noise on trigger line to GeoEel.

9.4 Winradio

Performance:

The Winradio worked very well, one of the two radios seems to perform better than the other. This has to be confirmed by Thomas Funck during processing of the sonobuoy data. The top of the bridge roof is an excellent antenna position.

Suggestions for improvements:

- During the LOMROG cruise continuous recording of sonobuoy data was set up using a Nanometrics recorder. In the future, RefTek recorder's available at GEUS could be used instead.

9.5 Instrument Container

Performance:

Overall the design of the interior is well laid out.

Suggestions for improvements:

- Minor items: clock on the wall, garbage container and one more drawer module with one small drawer for stationeries like pencils and rulers. "Pull-out writing desks" should be considered beneath all PC's.

- A local network should be installed by means of a router.

- For easy access there should be a USB port on each PC on the front panel. The existing two USB ports are hidden behind a lid.

- The afterdeck TFT monitor should be shock mounted to avoid the many vibrations it experiences now.

9.6 Streamer

Performance:

Good but very vulnerable in severe ice conditions – as all streamers are. The jumper cables were too short and did not have the correct connectors when they were delivered.

Suggestions for improvements:

- The five jumper cables have to be returned to Geometrics under warranty to get correct length and connectors.

- Each 50-m active section contains about 30 litres silicone. It is recommended to bring extra silicone for each section. Furthermore, empty containers for used silicone should be brought onboard. In addition, absorbents to clean up the deck after working with silicone are required.

- The filling system has to be improved by Geometrics. The filling screw needs a ball vent to prevent an over-pressurized streamer to leak silicone when changing from the pump-filling system to the screw.

9.7 Airgun

Performance:

The gun array worked well. All connectors are well protected and show no evidence of wear. The two near field hydrophones are a slightly exposed – and were damaged on one occasion.

Suggestions for improvements:

- The use of a depressor has been discussed thoroughly and after a long discussion there was agreement that using the depressor would have resulted in more damage than experienced. Furthermore, handling of the depressor is very complicated. The risk that the depressor itself will catch ice is also high.

- At a towing depth of 6 to 8 m, there might be a benefit of using the depressor in order to keep the air gun cluster down when the ship is running with four engines.

- To avoid the gun chambers to get filled with water under deployment and retrieval the pressure in the air gun has to be about 300 psi.

- The position of the depth transducer should be discussed before the next cruise.

9.8 Umbilical

Performance:

Very good, there is hardly any wear on the skin after being dredged through the ice.
Leakage test on the SPSU shows some electrical leakage that might be a malfunction in the slip ring or in the umbilical cable. This has to be investigated further when the equipment is back in Denmark.

Suggestions for improvements:

- The diameter of the part of the mud hose that supports the gun with trigger and air lines should be slightly larger.

- An angle grinder is needed to cut the mud hose to the correct length.

- During deployment of the reflection seismic problems getting the umbilical sheave into the frame were experienced. An improvised solution was found using a robust handmade steel pipe as lever to get the angle of the sheave right.

For future operations it should be considered to mount a steel plate behind the aft fitting of the sheave frame (see Fig. 8) to help getting the sheave in the right angle.

9.9 Winch

Performance:

After the latest modifications the winch worked very well.

Suggestions for improvements:

- The remote control needs to be adjusted since the response for paying cable in or out is too slow. Adjustments of the winch speed are very sensitive; another type of hydraulic valves might be needed in the hydraulic system.

- The control electronic box inside the winch container needs to be mounted much better. The plate inside is loose most likely as a consequence of the heavy transformers placed on the plate.

- Battery compartment of the remote control is broken and needs to be repaired or replaced.

- The pump for silicone should be mounted permanently in a suitable place in the winch container.

- A direct connection to the streamer in the streamer winch is needed, so the streamer can be tested without laying out the cable on deck.

9.10 Compressor

Performance:

The compressors performed very well without any problems.

Suggestions for improvements:

- The alarm monitor in the instrument container works well, but it would be preferable if the audible alarm can be switched off.

- The cooling water system is leaking. However, there is no evidence of water on the floor. The leaking could be caused by rolling and vibration of the ship. The two units are jumping quite a lot especially during icebreaking. The "leaking" occurs mostly at compressor 1.

- A 500-hours service has to take place when the compressors are back in Denmark.

9.11 Seismic crew

Performance:

The number of people in the seismic crew seems to work well for this type of multidisciplinary cruise where other scientific projects are running simultaneously. If the amount of seismic planned during a future cruise is considerably higher it should be considered to bring one or two extra persons.

Suggestions for improvements:

- With the present setup, only one person on watch would be needed. Everything can be controlled from the recording container on deck 4. The option with only one person would need direct contact with the bridge via a VHF radio.

- Deployment and retrieval require the following persons: One person on the bridge to be in direct contact with the bridge and the afterdeck and to decide when to deploy the equipment. Afterdeck: One person from the ship to operate the A-frame, one person to run the three winches, two persons at the very aft to handle the streamer and gun array, two persons to handle the gun array while moving this from deck to the very afterdeck and one person to keep radio contact with the person on the bridge.

9.12 Installation and Arrangement of the Seismic Equipment on *Oden*

The recording container is placed on deck 4 to avoid the vibrations on the afterdeck, which can be tremendous. However, if possible, the small crane in front of the container should be removed in order to have an undisturbed view to the aft of the ship. The arrangement of the containers on the afterdeck is very practical and gives a lot of working space. A lot of storage space in the upper container layer was provided as well.

9.13 Cooperation with *Oden's* Crew and the Other Science Projects on *Oden*

There was a very good cooperation with the watch officer and the deck crew when deploying or retrieving the seismic equipment. Despite the very difficult ice conditions both the navigators on board *50Llet Pobedy* and on *Oden* tried to maintain a steady course and speed. As very experienced icebreaker captains the two masters of *50 Let Pobedy* and of *Oden* very quickly established a very good cooperation between the two vessels. This cooperation made it possible to acquire seismic data under extreme ice conditions.

Due to the skilfulness of *Oden*'s fitter, a major problem of refitting the jumper cables with different connectors was solved. He was also extremely helpful solving other minor problems.

In general, there is a very positive attitude amongst the crew on *Oden* towards the scientific projects of the LOMROG expedition.

Other scientific projects running simultaneously during LOMROG supplemented each other:

- CTD measurements are essential for the multibeam data acquisition. Bathymetric data are indispensable for the Danish Continental Shelf Project.

- Subbottom profiler data and coring (gravity and piston corer) are providing the Danish Continental Shelf Project with important data on the youngest geological history of the region.

- Gravity data acquisition from *Oden* (see separate report).

- The ice coring project has easily been integrated into the LOMROG expedition.

9.14 *Oden* as a Platform for Further Seismic Investigations in the Arctic Ocean

Before *Oden* was chosen as a platform for bathymetric and seismic data acquisition in the area north of Greenland under the Danish Continental Shelf Project several alternative solutions were investigated (see report from the prestudy (Forprojekt) in 2002 and the evaluation in connection with the budget revision in January 2005). Since then, advanced deep water multi-beam and subbottom profiler equipment was installed on *Oden*.

In general *Oden* performed far better than expected:

- The seismic equipment designed for use on *Oden* behaved as planned. Airgun and streamer stayed at the planned depth (approx. 20 m) also under heavy ice breaking of *Oden* (full power on all four engines).

- Oden has a large and wide afterdeck with plenty of work space.

- After the latest modifications of the streamer winch, the seismic equipment can be launched very swiftly.

- The seismic equipment can easily be handled together with the coring equipment (rails) placed on the afterdeck.

- *Oden* keeps a large open wake behind the ship also in 10/10 of ice cover under light compression.

- Oden can keep an open wake behind the ship with no forward movement in 10/10 of ice cover, which facilitates easy deployment of the seismic equipment.

- Good arrangement of containers.

- Good cooperation with the Swedish Polar Research Secretariat.

- Good cooperation with other scientific projects onboard.

Suggestions for improvements:

- More flexibility during an expedition to go where ice conditions seem to be easiest (longer expedition periods), a longer period of assistance from a Russian nuclear icebreaker is required.

- Firm commitments in charter contract for Russian icebreaker.

- Problems under extreme ice conditions to follow in the wake behind the Russian nuclear icebreaker *50 Let Pobedy. 50 Let Pobedy* creates a lot of "slush ice", which is not easy to penetrate for *Oden.*

9.15 How to handle seismic data acquisition under extreme ice conditions

- Flexibility in planning.

- More information about the ice conditions.

- Stop when ice conditions are too severe. However, ice conditions are difficult to predict since they can vary from one ice flow to the next.

- Less equipment in the water.

9.16 Maintenance and Storage of the Seismic Equipment

- When the equipment is back in Århus the necessary maintenance, repair and replacement of lost equipment should take place as soon as possible and as soon as funding is available. External help should be used whenever possible.

- An extra storage container will be bought in order to house the complete equipment in five 20' containers.

- The problem of suitable storage space in Århus has to be solved.

- An inventory should be made of all parts and spare parts. Spare parts should be organized in their correct storage containers.

- A list of damaged equipment has to be prepared together with a budget for the replacement.

- All manuals now only available as PDF files have to be printed and all manuals should also be organized as PDF files on one CD-ROM.

- All software should be copied to one CD-ROM.

9.17 Other Use of the Seismic Equipment

- Prior to a new Arctic cruise it is imperative that the equipment is tested during a designated test cruise or during other scientific cruises in ice free waters.

- In order to train new people, it is important to introduce students, new technicians and new geophysicists to the equipment.

- In order to maintain the expertise and also to be able to test the equipment, it is very important that the equipment is used in other projects, i.e. under the umbrella of the new Geocenter Danmark.

10. Ice Conditions and Information Sources

By Trine Dahl-Jensen, Geological Survey of Denmark and Greenland, and Rene Forsberg, Danish National Space Center, DTU

During a cruise in the Arctic Ocean, knowledge of the ice conditions is important both for the navigation of the vessel and as a research topic. The ice conditions encountered during the LOMROG cruise were severe. The LOMROG cruise operated in the vicinity of the Lomonosov Ridge north of Greenland, a region with the heaviest ice conditions in the Arctic with ice thicknesses in excess of 3 m, often under intense pressure with few or no leads (Fig. 32).

During LOMROG, operational information about the ice was obtained and used in different ways. In addition, the ice thickness was measured on a daily basis. Measured ice thicknesses were generally in the range of 2.5-3.5 m in areas with heaviest ice conditions.

Figure 32. *Left: Typical ice conditions; right: View from the bridge of Oden.*

10.1 Reconnaissance from the Bridge

Reconnaissance from the bridge was used for local navigation and for planning the next ship's track over the next couple of miles (Fig. 32). A special measuring stick was mounted on the sides of *Oden* allowing a visual estimation of ice thickness from turned-over ice floes alongside *Oden*.

10.2 Helicopter Reconnaissance

When navigating in dense ice, helicopter reconnaissance was made to plan the ship's route (Fig. 33). Due to the lack of a meteorologist onboard *Oden*, the helicopter had a maximum range from the vessel of only 20 nautical miles. The helicopter track is automatically logged on *Oden*, and can be put on the Helmsman's display. Thus the helicopter could simply fly the best route observed and *Oden* then followed the track on the Helmsman's display for the next hours. *Oden* generally followed leads, and avoided – where possible – areas of thick multiyear flows and ridges.

Figure 33. *Ice reconnaissance by helicopter with 50 Let Pobedy in background.*

10.3 Envisat and Radarsat Images

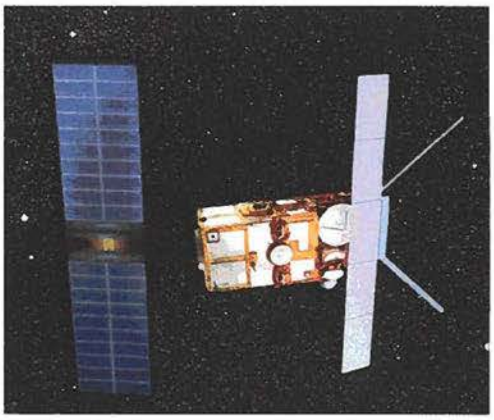


Figure 34. *Envisat satellite.*

Throughout the cruise Envisat (and a few Radarsat) SAR images were received on a daily basis by email from Leif Toudal Pedersen, Danish National Space Center, DTU. Envisat and Radarsat are both C-band imaging slant-looking radar systems operating in near-polar orbits, where data for specific regions are acquired in near-real time upon request. Both requested and routine data acquisitions were used. The images were acquired from the European Space Agency (ESA) and the Canadian Radarsat distributor, and then geo-rectified and sampled at a lower resolution in two designated areas north of Greenland and Svalbard. The images were useful for overall planning purposes within a longer time frame but not for real time navigation.

The resolution of the ENVISAT images was generally 300 m (Figs. 35 and 36), but frequently also smaller areas in 100-m resolution were received. Here the positions of *Oden* and *50 let Pobedy* could usually be seen (Fig. 37). The size of the images was 200-400 kB, which is close to the upper limit for downloading through the Swedish Polar Research Secretariat's Iridium mail system. The usefulness of the Envisat imagery was first and foremost for seeing the direction of ridges and leads. In areas with heaviest ice conditions the images showed few features and it was not possible to discriminate between first-year and multi-year ice floes. Ice movements, derived from feature analysis of sequential SAR scenes, were useful in evaluating the direction of the predominant ice pressure.

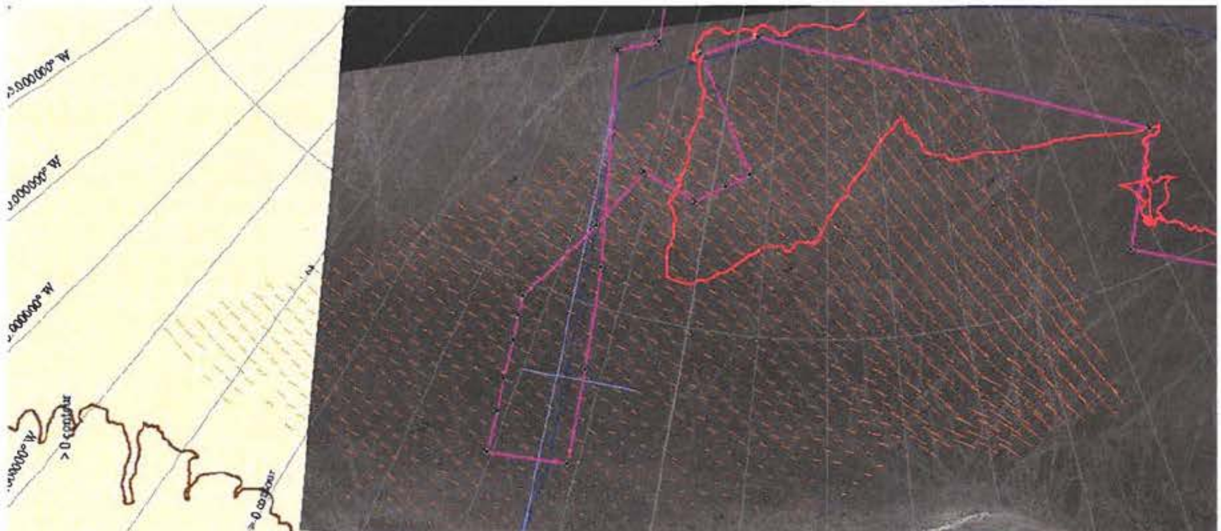


Figure 35. *Envisat image; overview (300 m resolution) over the Lomonosov Ridge area, showing 10/10 ice coverage with a SE ice drift. Oden's actual track is shown in red and the planned track in pink, here shown in Global Mapper GIS system.*

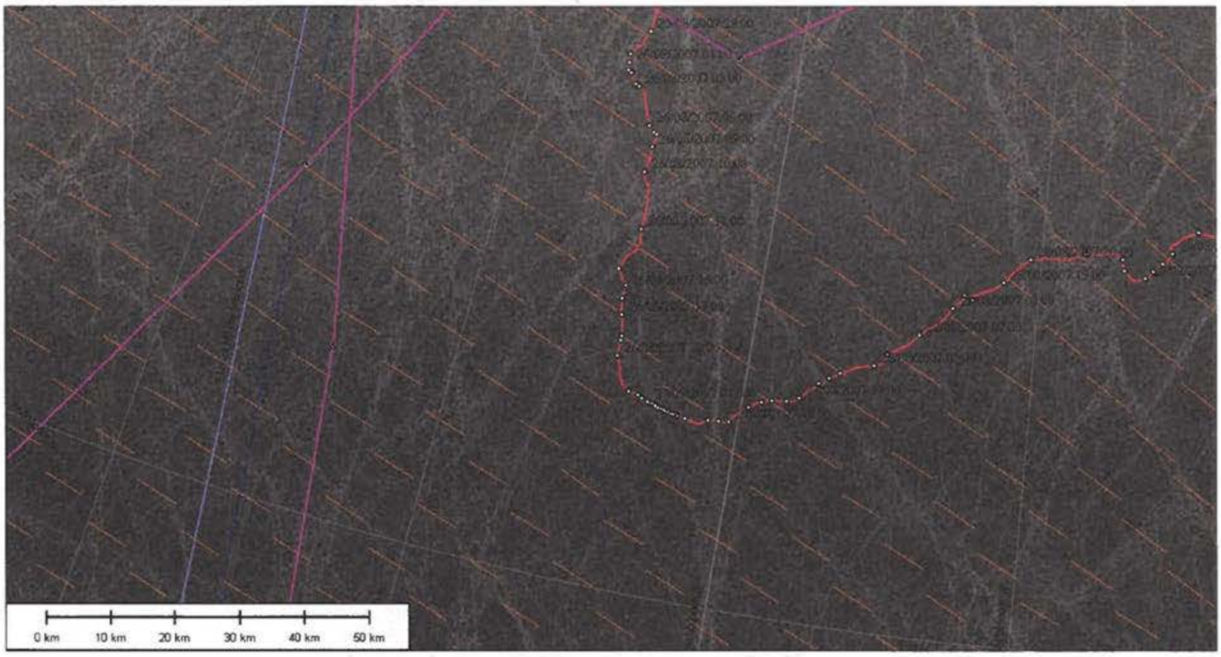


Figure 36. *Detail of Envisat imagery of Fig. 35, showing the irregular track of Oden in the heavy ice.*

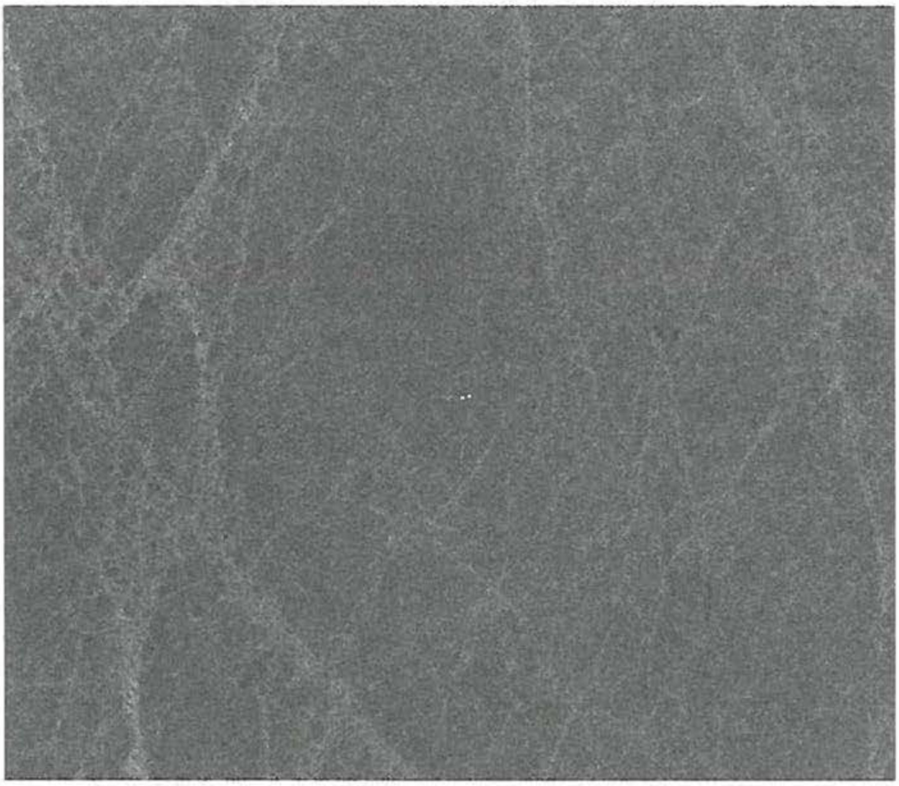


Figure 37. *100 m resolution Envisat image. In the centre of the image (28 August, 2007) Oden and 50 Let Pobedy can be seen as two white dots. The track of the two vessels is also visible as a "snail track" through the dense ice.*

10.4 Sea Ice Concentration Maps from Passive Microwave

Satellite passive microwave methods provide an estimate of the ice concentration. These maps are dependent on the algorithm used for deriving the concentration, and their usefulness in 10/10 ice conditions are somewhat questioned. During the LOMROG cruise concentration maps from the University of Bremen web service (AMSR Sea Ice Maps, IUP University of Bremen, http://www.iup.uni-bremen.de:8084/amsr/amsre.html, Figs. 38 and 39) were used. The maps were very useful to determined the position of the ice edge, and of limited use else, with some indications from the crew that the lighter areas seen on the example of Fig.38 also seemed occasionally to be easier to navigate through.

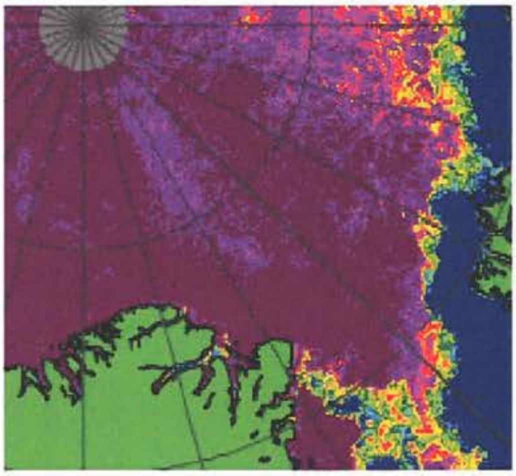


Figure 38. *Example of sea-ice concentration map of the LOMROG region*

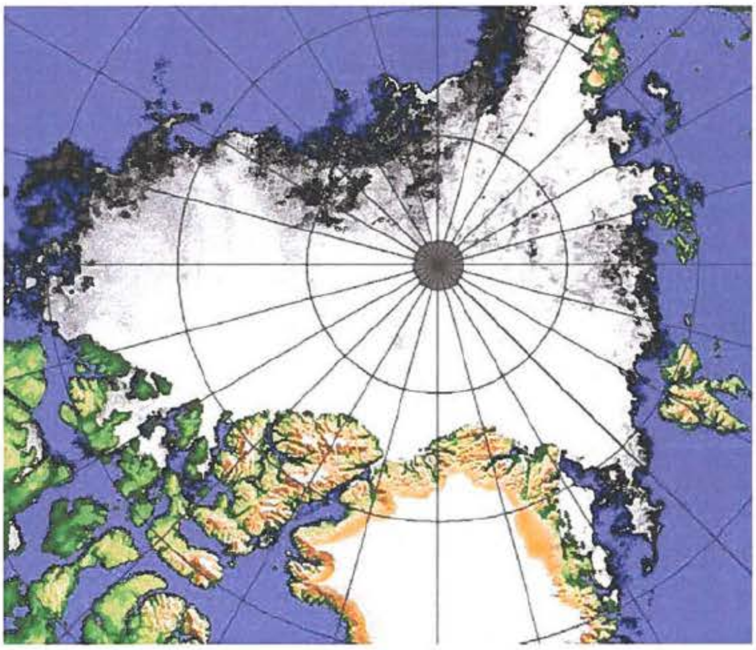


Figure 39. *Sea ice concentration in the Arctic (August 12, 2007). Although 2007 had the least sea-ice coverage ever recorded, ice conditions north of Greenland and Canada remained extraordinarily severe.*

10.5 Ice Drift information; Feature Recognition and Buoys

Information on ice drift was also received on a daily basis, both in the form of buoy positions from the IABP (International Arctic Buoy Project), and feature analysis performed on Envisat images approximately 24 h apart. The drift information was useful in evaluating the optimum travel direction when the compression in the ice was large; the ship then attempted to travel parallel to the drift direction. *Oden* itself was the best local source of information on drift; when stationary for station work or stuck in the ice, the actual ice drift is readily logged by the ship's GPS.

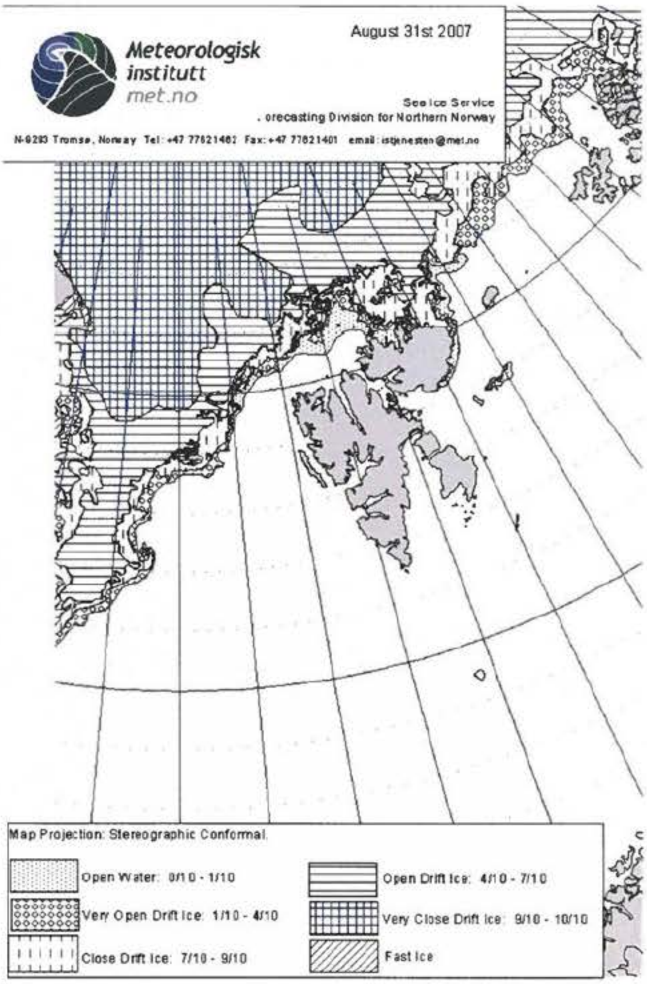


Figure 40. *Example of operational ice chart from Norwegian Meteorological Institute (http://retro.met.no/kyst_og_hav/iskart.html).*

10.6 Interpreted Ice Maps from Norway and Denmark

Both the Danish Meteorological Institute (DMI) and the Norwegian sister institution publish interpreted ice maps over the Greenland Sea. Available images were sent to *Oden* by Leif Toudal Pedersen when relevant (Fig. 40).

10.7 Planning and Subsequent Changes

When planning the LOMROG cruise, ice conditions in the southern part of the Lomonosov Ridge close to Greenland were expected to be most severe. This area has not been reached by surface vessels previously. Just before the LOMROG cruise started numerous leads were visible on the Envisat SAR images from August 9, 2007 (Fig. 41). However, when the area was actually reached the situation was quite different with no leads and many pressure ridges (Fig. 42). These ice conditions made changes in the plan for *Oden* necessary and not all planed activities could be carried out. It is expected that more could have been achieved if ice conditions as seen on Fig. 41 were encountered.

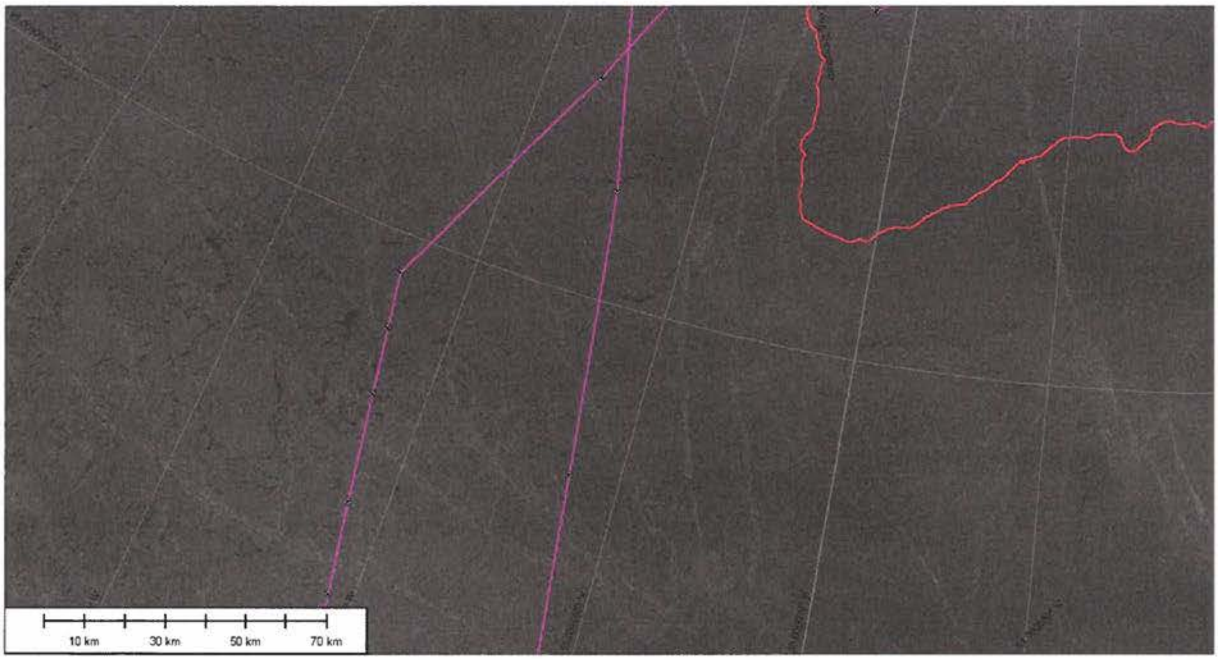


Figure 41. *Envisat SAR image from August 9, 2007, showing the southernmost part of the Lomonosov Ridge towards Greenland. The planned track is shown in pink and the actual track is marked in red. The dark areas are leads and thinner ice.*

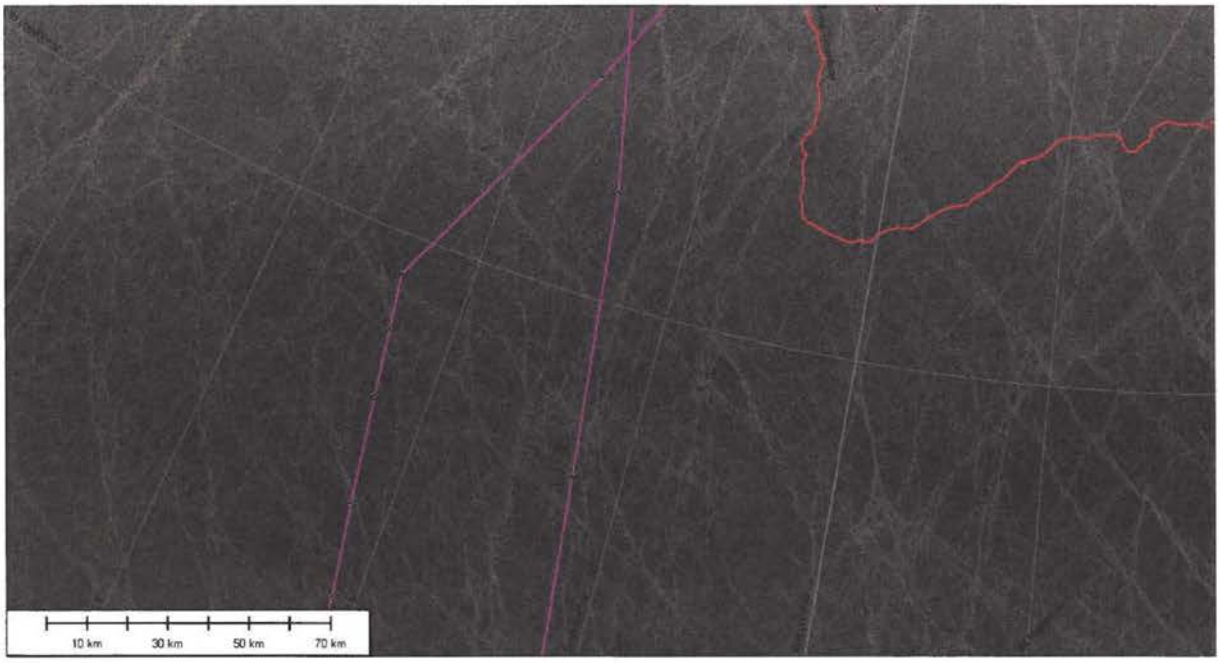


Figure 42. Envisat SAR image over the same area as Fig. 41, but two weeks later. Now pressure ridges (white lines) dominate the area, and all indications of leads are gone.

10.8 Description of ice conditions along the track

Oden entered the polar pack ice on August 16, 2007, and remained in 10/10 of ice until the ice was left en-route to NE Greenland on September 11, 2007. Navigation was difficult in areas with sea ice under compression. While crossing the Amundsen Basin, ice compression steadily increased, and successful acquisition of the seismic data on Line 1 (August 19 – 21, 2007) was only possible with the support of *50 Let Pobedy*. On the Lomonosov Ridge, while acquiring multibeam data and coring from August 24 – 25, 2007, the ice compaction eased slightly, and then increased to extremely difficult conditions at the bathymetric trough where the Lomonosov Ridge connects with the Greenland Shelf. Here ice compression was intense and combined with thick multiyear ice floes, many pressure ridges and rubble fields; overall conditions were very difficult. *Oden* was not able to manoeuvre on its own in this area, and also *50 Let Pobedy* was occasionally in trouble and got stuck. Ice conditions made it impossible to go farther west. The 2nd seismic line was acquired August from 26 – 27, 2007 in very heavy ice conditions and farther to the east than originally planned.

Moving east again, the compression slowly eased, and when *50 Let Pobedy* left *Oden* on August 31, 2007, *Oden* was again in manageable ice conditions on Morris Jesup Rise. Due to the prevailing lead systems and ice compression, a more easterly route was chosen for the transit to the work area on the East Greenland Ridge.

On the North East Greenland shelf, ice conditions varied from open water to 8-9/10 ice with out compression. Under these ice conditions it was easy to navigate for *Oden*, and the seismic and bathymetric program was carried out according to plan.

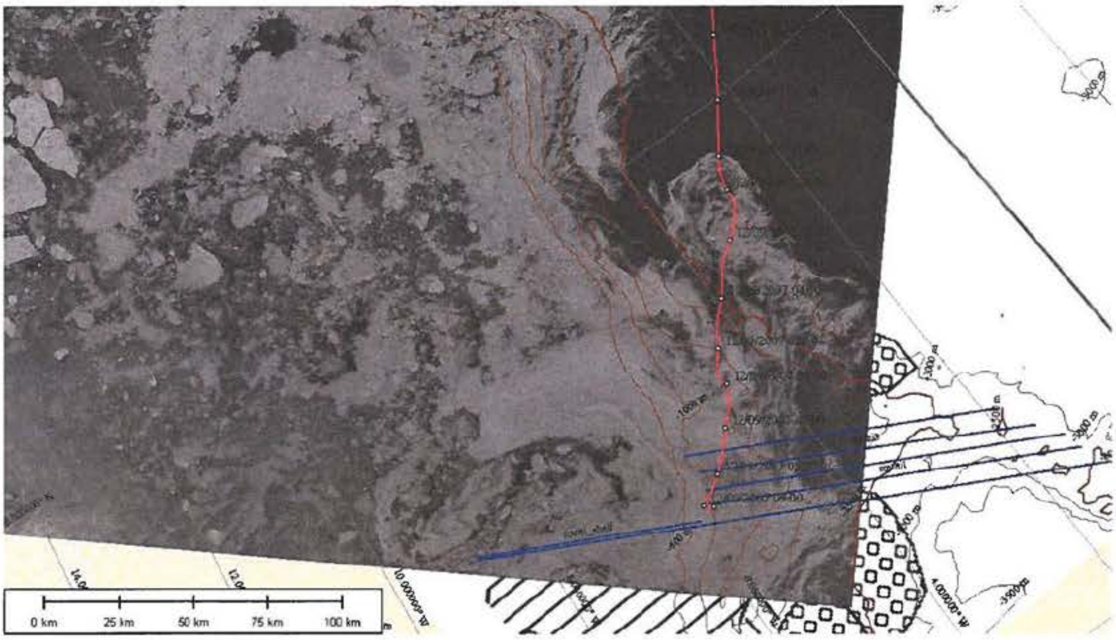


Figure 43. *Envisat image (September 11, 2007) of the ice in NE Greenland with the planned seismic and multibeam lines in blue. Oden's track towards the area is shown in red. An ice map from the Norwegian Meteorological Institute is underlying the satellite image.*

11. Acknowledgements

We wish to thank the Swedish Polar Research Secretariat, Martin Jakobsson (Stockholm University) and the crew of *Oden* and of *50 Let Pobedy* for excellent cooperation during the LOMROG cruise in 2007. The seismic equipment used during LOMROG was developed based on experiences kindly shared with us by our colleagues Arthur Grantz, Yngve Kristoffersen and Wilfried Jokat.

12. Appendices and Enclosures

Appendices:

Appendix 1: *Oden* offset measurements

Appendix 2: Seismic log sheets

Appendix 3: Seismic tape inventory

Appendix 4: Sonobuoy appendices

- **A** Record sections for all sonobuoys
- **B** Technical specifications VHF antenna MD G3
- **C** Technical specifications sonobuoy receiver WR-2902e
- **D** Technical specifications Taurus seismometer from Nanometrics
- **E** Technical specifications sonobuoy AN/SSQ-53D(2) from ULTRA Electronics
- **F** Technical specifications hydrophone Teledyne/Benthos AQ-2000
- **G** Technical drawing of the hydrophone connection to the Taurus recorder
- **H** Technical specifications Mark Products L4 1-Hz vertical geophone

Enclosures as digital files on enclosed CD-ROM:

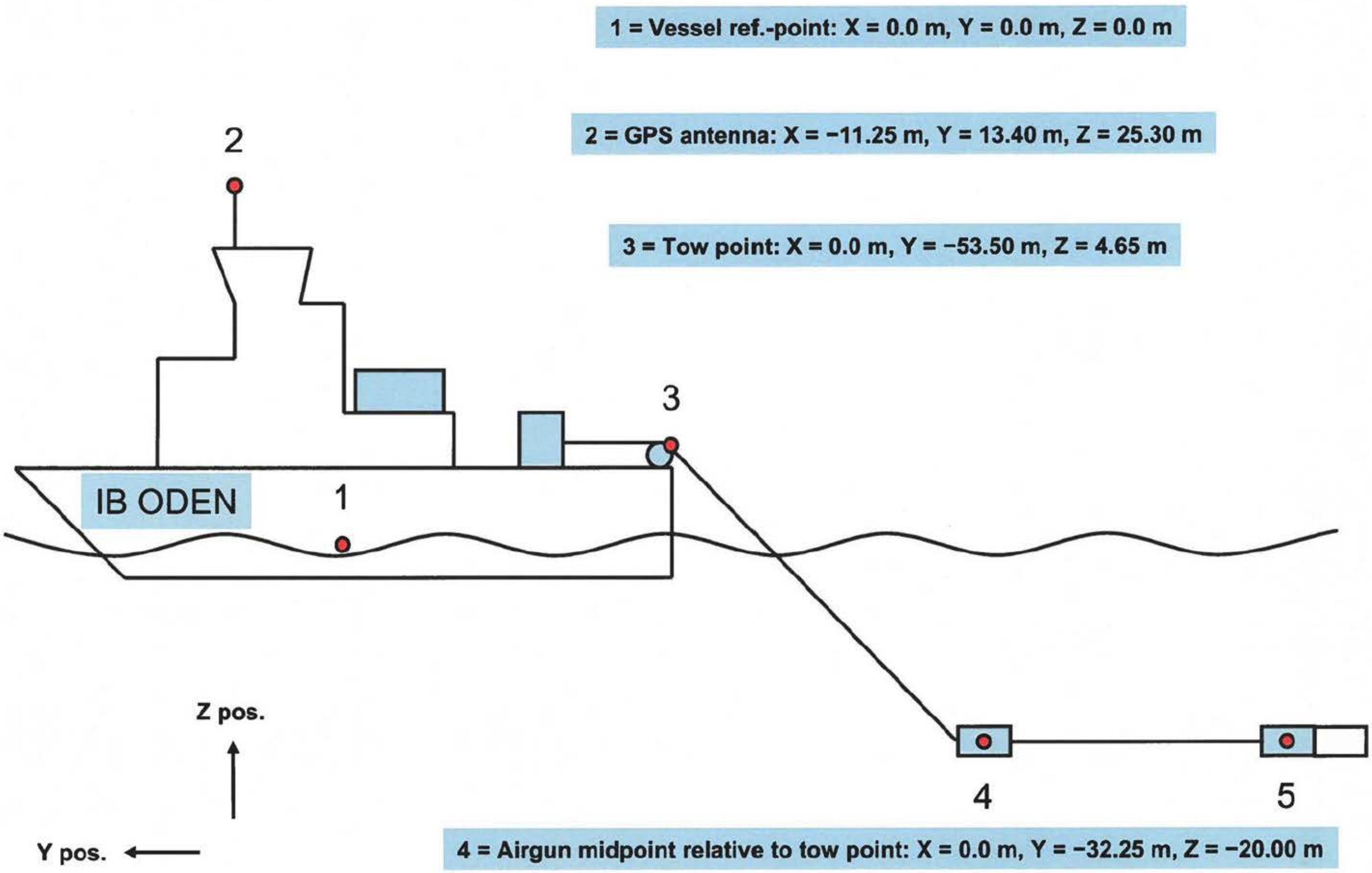
Enclosure 1: Detailed description of the multi-channel seismic acquisition equipment

Enclosure 2:

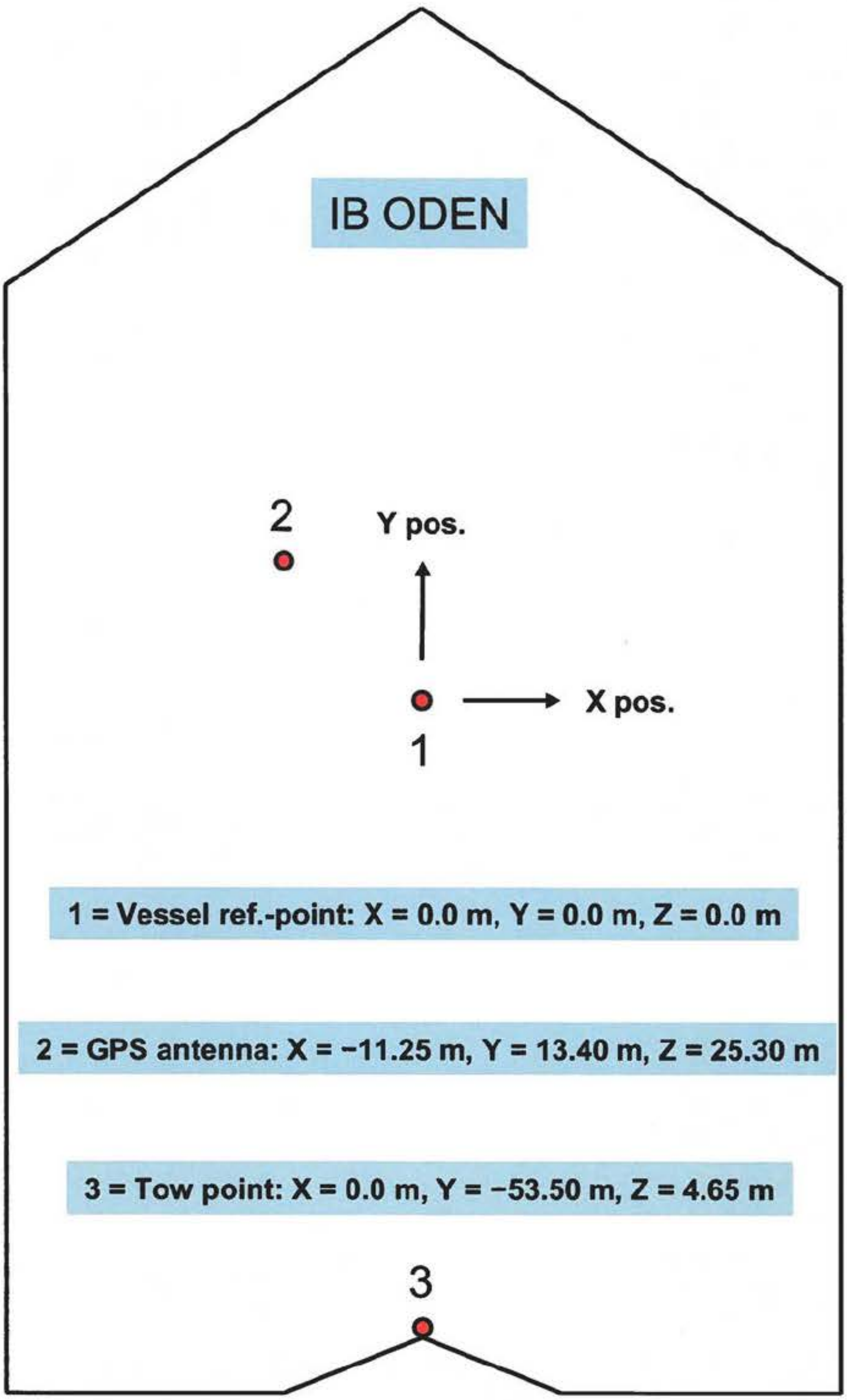
> Martin Jakobsson, Christian Marcussen & LOMROG Scientific Party: Lomonosov Ridge off Greenland 2007 (LOMROG) – Cruise Report, 122 pp. Special Publication Geological Survey of Denmark and Greenland, Copenhagen, Denmark.

Enclosure 3: Navigation data

Appendix 1: *Oden* offset measurements



Oden: Offset points - sideward look



***Oden*: Offset points - topside look**

Appendix 2: Seismic log sheets

Date:	19-08-2007	Marine Survey - General Information	Line:	LOMROG07_01

Cruise:	LOMROG 2007	Ship:	IB Oden	Location:	Arctic Ocean

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-84.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	40		53	50	50	50	50	50	50
Serial no. live sections									
Serial no. depth transducer (front of section)				1026	1028	1025	1031	1024	1038
Serial no. A/D converter (front of section)				1149	1152	1153	1154	1151	1157

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
Planned depth (m):	20

Seismic Instruments:	
Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	6
Sample Rate (ms):	1
Record Length (ms):	11000
No of recording chs:	48
No of auxilliary chs:	4

Streamer:	
Type:	Geometrics GeoEel
Length of tow section (m):	93
Length of live section (m):	300
No. of live sections:	6
No. of channels:	48
No. of channels/live section:	8
channel interval (m):	6.25
No. of hydrophones/channel:	8
Serial no. Vibration section:	1003
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	1082
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Coordinate output to SEG-D header has been gun-pos for x,y and vessel-pos for lat,long. Gun-pos (x,y and lat,long not in custom-file)
Longitude from pole set to -25° instead of 0°

Date:	19-08-2007	Marine Survey - General Information	Line:	LOMROG07_01A

Cruise:	LOMROG 2007	Ship	IB Oden	Location:	Arctic Ocean

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-84.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	40		53	50	50	50	50	50	50
Serial no. live sections									
Serial no. depth transducer (front of section)				1026	1028	1025	1031	1024	1038
Serial no. A/D converter (front of section)				1149	1152	1153	1154	1151	1157

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
Planned depth (m):	20

Seismic Instruments:	
Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	6
Sample Rate (ms):	1
Record Length (ms):	11000 / 9000
No of recording chs:	48
No of auxilliary chs:	4

Streamer:	
Type:	Geometrics GeoEel
Length of tow section (m):	93
Length of live section (m):	300
No. of live sections:	6
No. of channels:	48
No. of channels/live section:	8
channel interval (m):	6.25
No. of hydrophones/channel:	8
Serial no. Vibration section:	1003
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	1082
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Coordinate output to SEG-D header has been gun-pos for x,y and vessel-pos for lat,long. Gun-pos (x,y and lat,long not in custom-file)
Longitude from pole set to -25° instead of 0°

Date:	19-08-2007	Marine Survey - General Information	Line:	LOMROG07_Per

Cruise:	LOMROG 2007	Ship:	IB Oden	Location:	Arctic Ocean

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-84.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		40		53	50	50	50	50	50	50
Serial no. live sections										
Serial no. depth transducer (front of section)					1026	1028	1025	1031	1024	1038
Serial no. A/D converter (front of section)					1149	1152	1153	1154	1151	1157

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	6
Sample Rate (ms):	1
Record Length (ms):	9500
No of recording chs:	48
No of auxilliary chs:	4

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	93
Length of live section (m):	300
No. of live sections:	6
No. of channels:	48
No. of channels/live section:	8
channel interval (m):	6.25
No. of hydrophones/channel:	8
Serial no. Vibration section:	1003
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	1082
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Coordinate output to SEG-D header has been gun-pos for x,y and vessel-pos for lat,long. Gun-pos (x,y and lat,long not in custom-file)
Longitude from pole set to -25° instead of 0°

Date:	19-08-2007	Marine Survey - General Information	Line:	LOMROG07_01E

Cruise:	LOMROG 2007	Ship:	IB Oden	Location:	Arctic Ocean

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-84.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	40		53	50	50	50	50	50	50
Serial no. live sections									
Serial no. depth transducer (front of section)				1026	1028	1025	1031	1024	1038
Serial no. A/D converter (front of section)				1149	1152	1153	1154	1151	1157

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	6
Sample Rate (ms):	1
Record Length (ms):	9500
No of recording chs:	48
No of auxilliary chs:	4

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	93
Length of live section (m):	300
No. of live sections:	6
No. of channels:	48
No. of channels/live section:	8
channel interval (m):	6.25
No. of hydrophones/channel:	8
Serial no. Vibration section:	1003
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	1082
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Coordinate output to SEG-D header has been gun-pos for x,y and vessel-pos for lat,long. Gun-pos (x,y and lat,long not in custom-file)
Longitude from pole set to -25° instead of 0°

Date:	20-08-2007	**Marine Survey - General Information**	**Line:**	LOMROG07_02

Cruise:	LOMROG 2007	**Ship:**	IB Oden	**Location:**	Arctic Ocean		

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-84.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	40		53	50	50	50	50	50	50
Serial no. live sections									
Serial no. depth transducer (front of section)				1026	1028	1025	1031	1024	1038
Serial no. A/D converter (front of section)				1149	1152	1153	1154	1151	1157

Navigation:		**Transformation parameters:**			
Software:	NaviPac	Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Projection:	Universal Polar Stereographin, N	Inverse flattening:	297	False easting (m):	2000000
Datum:	WGS84	Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:		**Seismic Instruments:**		**Streamer:**	
Type:	Cluster w. Sercel GI and G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. GI-Gun:	4425	Lowcut filter (Hz):	out	Length of tow section (m):	93
Volume GI (cu.inch):	250-105	Lowcut filt. (dB/Oct):	out	Length of live section (m):	300
Serial no. G-Gun:	18391	Highcut filter (Hz):	anti-alias	No. of live sections:	6
Volume G (cu.inch):	250	Highcut filt. (dB/Oct):	anti-alias	No. of channels:	48
Delay:	**16mS**	Gain Setting (dB):	6	No. of channels/live section:	8
Pressure (bar):	200.00	Sample Rate (ms):	1	channel interval (m):	6.25
Planned depth (m):	20.00	Record Length (ms):	9500	No. of hydrophones/channel:	8
		No of recording chs:	48	Serial no. Vibration section:	1003
		No of auxilliary chs:	4	Serial no. 10 Mb repeater:	? (inside slipring)
				Serial no. 100 Mb repeater:	1082
				Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Coordinate output to SEG-D header has been gun-pos for x,y and vessel-pos for lat,long. Gun-pos (x,y and lat,long not in custom-file)
Longitude from pole set to -25° instead of 0°

Date:	26-08-2007	**Marine Survey - General Information**	**Line:**	LOMROG07_03

Cruise:	LOMROG 2007	**Ship:**	IB Oden	**Location:**	Arctic Ocean

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-84.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		40		53	50	50	50	50	50	50
Serial no. live sections										
Serial no. depth transducer (front of section)					1035	1034	1039	1036	1021	1033
Serial no. A/D converter (front of section)					1149	1156	1164	1159	1155	1165

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	6
Sample Rate (ms):	1
Record Length (ms):	8500
No of recording chs:	48
No of auxilliary chs:	4

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	93
Length of live section (m):	300
No. of live sections:	6
No. of channels:	48
No. of channels/live section:	8
channel interval (m):	6.25
No. of hydrophones/channel:	8
Serial no. Vibration section:	1003
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	1082
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Streamer section 1023 has a leakage of 1300 Mohm, section 1026 has been subject to stretching in the ice and section 1021 have been refilled with silicon gel
Longitude from pole set to -25° instead of 0°

Date:		Marine Survey - General Information	Line:	LOMROG07_03A

Cruise:	LOMROG 2007	Ship:	IB Oden	Location:	Arctic Ocean

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-84.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	40		53	50	50	50	50	50	50
Serial no. live sections									
Serial no. depth transducer (front of section)				1035	????	1036	1021	1033	
Serial no. A/D converter (front of section)				1149	????	1159	1155	1165	

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	6
Sample Rate (ms):	1
Record Length (ms):	8500
No of recording chs:	40
No of auxilliary chs:	4

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	93
Length of live section (m):	250
No. of live sections:	5
No. of channels:	40
No. of channels/live section:	8
channel interval (m):	6.25
No. of hydrophones/channel:	8
Serial no. Vibration section:	1003
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	1082
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Streamer section 1023 has a leakage of 1300 Mohm, section 1026 has been subject to stretching in the ice and section 1021 have been refilled with silicon gel
Longitude from pole set to -25° instead of 0°

Date:	13-09-2007	Marine Survey - General Information	Line:	LOMROG07_04

Cruise:	LOMROG 2007	Ship:	IB Oden	Location:	Arctic Ocean

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length Vib section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
X (m)	-11.25	X (m)	0.00	X (m)	2.15		40		103	50	50	50	50		
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00	Serial no. live sections									
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00	Serial no. depth transducer (front of section)				1042	1037	1041	1035		
Towpoint ship		Airgun midpoint relative to towpoint		Channel 1 midpoint relative to towpoint		Serial no. A/D converter (front of section)				1144	1143	1140	1141		
X (m)	0.00	X (m)	0.00	X (m)	0.00										
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-134.50										
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00										

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:		Seismic Instruments:		Streamer:	
Type:	Cluster w. Sercel GI and G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. GI-Gun:	4425	Lowcut filter (Hz):	out	Length of tow section (m):	93
Volume GI (cu.inch):	250-105	Lowcut filt. (dB/Oct):	out	Length of live section (m):	200
Serial no. G-Gun:	18391	Highcut filter (Hz):	anti-alias	No. of live sections:	4
Volume G (cu.inch):	250	Highcut filt. (dB/Oct):	anti-alias	No. of channels:	32
Delay:	**12-15 mS**	Gain Setting (dB):	6	No. of channels/live section:	8
Pressure (bar):	200	Sample Rate (ms):	1	channel interval (m):	6.25
Planned depth (m):	20	Record Length (ms):	9500	No. of hydrophones/channel:	8
		No of recording chs:	32	Serial no. Vibration section:	1003
		No of auxilliary chs:	4	Serial no. 10 Mb repeater:	? (inside slipring)
		Dead ch	25,28,29,30,31	Serial no. 100 Mb repeater:	1082 / ???
				Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Streamer section 1023 has a leakage of 1300 Mohm, section 1026 has been subject to stretching in the ice and section 1021 have been refilled with silicon gel
Longitude from pole set to -25° instead of 0°
Section 4 is reversed - depth transducer at the tail end. One extra repeater btw. the two Vib sections. ADC module 1147 bad, changed before line start

Date:	13-09-2007	Marine Survey - General Information	Line:	LOMROG07_04A

Cruise:	LOMROG 2007	Ship:	IB Oden	Location:	Arctic Ocean

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		**Airgun midpoint relative to towpoint**		**Channel 1 midpoint relative to towpoint**	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-134.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length Vib section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	40		103	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				1042	1037	1041	1035		
Serial no. A/D converter (front of section)				1144	1143	1140	1141		

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**12-15 mS**
Pressure (bar):	200
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	6
Sample Rate (ms):	1
Record Length (ms):	9500
No of recording chs:	32
No of auxilliary chs:	4
Dead ch	25,28,29,30,31

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	93
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6.25
No. of hydrophones/channel:	8
Serial no. Vibration section:	1003
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	1082 / ???
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Streamer section 1023 has a leakage of 1300 Mohm, section 1026 has been subject to stretching in the ice and section 1021 have been refilled with silicon gel
Longitude from pole set to -25° instead of 0°
Section 4 is reversed - depth transducer at the tail end. One extra repeater btw. the two Vib sections.

Date:	13-09-2007	**Marine Survey - General Information**	**Line:**	LOMROG07_04B

Cruise:	LOMROG 2007	**Ship:**	IB Oden	**Location:**	Arctic Ocean

GPS antenna		Refpoint ship		Gyro	
X (m)	-11.25	X (m)	0.00	X (m)	2.15
Y (m)	13.4	Y (m)	0.00	Y (m)	7.00
Z (m)	25.3	Z (m)	0.00	Z (m)	34.00
Towpoint ship		**Airgun midpoint relative to towpoint**		**Channel 1 midpoint relative to towpoint**	
X (m)	0.00	X (m)	0.00	X (m)	0.00
Y (m)	-53.25	Y (m)	-32.25	Y (m)	-134.50
Z (m)	4.65	Z (m)	-20.00	Z (m)	-20.00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length Vib section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		40		103	50	50	50			
Serial no. live sections										
Serial no. depth transducer (front of section)					1042	1037	1041			
Serial no. A/D converter (front of section)					1144	1143	1140			

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378388	Latitude of true scale:	+ 81° 07'
Inverse flattening:	297	False easting (m):	2000000
Scale factor at pole:	0.994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**12-15 mS**
Pressure (bar):	200
Planned depth (m):	20

Seismic Instruments:	
Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	6
Sample Rate (ms):	1
Record Length (ms):	9500
No of recording chs:	24
No of auxilliary chs:	4

Streamer:	
Type:	Geometrics GeoEel
Length of tow section (m):	93
Length of live section (m):	150
No. of live sections:	3
No. of channels:	24
No. of channels/live section:	8
channel interval (m):	6.25
No. of hydrophones/channel:	8
Serial no. Vibration section:	1003
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	1082 / ???
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth not regularly scanned, only when disarmed or when loosing shots. Noted manually when changes are noticed
Tow length approx. 43 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Streamer section 1023 has a leakage of 1300 Mohm, section 1026 has been subject to stretching in the ice and section 1021 have been refilled with silicon gel
Longitude from pole set to -25° instead of 0°
Section 4 is reversed - depth transducer at the tail end. One extra repeater btw. the two Vib sections.

Cruise: LOMROG 2007 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 1/7

Line ID	Date d-m-y	SOL/EOL	H:M	Start/End Latitude N		Start/End Longitude E/W(-)		Remarks gun/streamer depths	Data storage LTO-2	Data storage HDD	Data storage Navigation	Navipac
1	19-08-2007	146	01:29	87°	00'	9°	46'	Gun skyder ej ca 50 sp	101	E:\Lomrog07_0	070819C000	
		256		°	'	°	'	Russer sidder fast, vi drive				
		256		°	'	°	'	F! paa geo - nyrt scan af d				
		258		°	'	°	'	Vi sejler igen				
		260		°	'	°	'	Vi sidder fast				
		300	03:04	°	'	°	'	Gun naesten ude af vande				
		323		°	'	°	'	Sonar buoy 1-1 kastet I va				
		352		°	'	°	'	Meget stoj - da vi liger har				
		362		°	'	°	'	midste et par skud, pga fa				
		363		°	'	°	'					374
		366	03:20	°	'	°	'	Vi sidder fast				
		368	03:45	°	'	°	'	Vi sejler igen				379
		389		°	'	°	'	Meget stoj pa streamer				
		408		°	'	°	'	Fine data pa sonar bouy				419
		430	04:09	87°	3,2'	8°	48,6'	gun 23 m				441
		507		°	'	°	'	Gun fanget at is - oppe pa				
		567		°	'	°	'	Vi sidder fast				579
		568		°	'	°	'	Vi sejler igen				580
		577		°	'	°	'	Nogle skud mangler				591
		588		°	'	°	'	Vi sidder fast				604
		593		°	'	°	'	Vi sejler igen				609
		596		°	'	°	'	CNT-2 ingen trig, restart af				
01A		650		°	'	°	'	Nyt Tape og Line pa CNT-	102	E:\Lomrog07_0	070819C000	652
		676	05:40	87°	05,4'	8°	01,1'					682
		835		°	'	°	'	Nogle skud mangler, spee				862
		965	06:59	°	'	°	'	vi sidder fast				1007
		967	07:13	°	'	°	'	Sejler igen				1010
		1218	08:14	87°	11,5'	6°	07,2'	Der har vaeret en del fejltri				1298
		1328	08:39	87°	12,6'	5°	47,3'	25///18/11/21/22/24/27				1407
		1608	09:46	87°	15,4'	4°	51,9'					1695
		1732	10:15	87°	16,56'	4°	25,57'	Sonar buoy 1A-2 kastet i v				1822
		1958	11:04	87°	18.5'	3°	32.7'	tryk 195-203 bar				2051
		?		°	'	°	'	23///18/21/19/22/26/15				?
		2484		°	'	°	'	Gun og streamer ude af va	Ch. 48 er syg			

Cruise: LOMROG 2007 | **Ship:** IB Oden | **Location:** Arctic Ocean | **Page:** 2/7

Line ID	Date d-m-y	SOL/EOL	H:M	Start/End Latitude N				Longitude E/W(-)				Remarks gun/streamer depths	Data storage LTO-2	HDD	Navigation	Navipac
01A	19-08-2008	2538	13:27	87	°	23.9	'	1	°	20	'		102	E:\Lomrog07_0	070819C000	2657
		2820	14:35		°		'		°		'	Sidder fast i isen. Russ. Hj				
		2825	15:00	87	°	26,29	'	0	°	7,0	'	Meget langsomt fremad, ru				2826
		2862	15:33	87	°	26,57	'	0	°	-3,9	'	Saa er vi fri igen				2993
		?			°		'		°		'	19///27/17/18/22/28/25				?
		3000			°		'		°		'	Sonar buoy 1A-3 sat I van				3134
		?			°		'		°		'	19///20/20/22/24/30/32				?
		3023	16:24	87	°	27,9	'	0	°	-41,7	'	Fast I isen igen, russ hjael				3156
		3029		87	°	27,9	'	0	°	-44,9	'	Fri igen				3162
		3047			°		'		°		'	20///22/23/25/28/29/31				3181
		3092			°		'		°		'	>25///18/18/20/23/24/27				3226
		3118	17:08	87	°	28,6	'	-1	°	-5,2	'	Fast I isen igen, russ hjael				3252
		3119	17:21	87	°	28,6	'	-1	°	-6,9	'	Fri igen				
		3138	ca.17:20:00		°		'		°		'	Fast igen				
			17:42		°		'		°		'	Fri igen				
		3184	17:52		°		'		°		'	SOG 5 kn				
		3188	17:54		°		'		°		'	Fast i isen				3329
		3190	18:21	87	°	29,2	'	-1	°	29,8	'	fri igen Navipac har reset,				138
					°		'		°		'	logfile 070819C000.npd				
		3231	18:34	87	°	29,5	'	-1	°	37,4	'	Fast i isen, "50 Let Pobedy				186
		3232	18:54	87	°	29,5	'	-1	°	38,9	'	Fri igen				187
		3233			°		'		°		'	Reg length 9 sec, max spe				
		3234			°		'		°		'	Vi sidder fast				191
		3240			°		'		°		'	Vi sejler igen				
		3242			°		'		°		'	Vi siddr fast				199
		3243			°		'		°		'	Vi sejler igen				200
		3280			°		'		°		'					237
		3341			°		'		°		'	Gun I ca. 6,4 m ????				
		3452			°		'		°		'	Jeg vil tror at gun er I ca. 1				270
		3461			°		'		°		'	fart ca. 3.8, stoj fra skib				418
		3472			°		'		°		'	EOL				
01B	ingen filer				°		'		°		'	Ingen filer paa HD				
Per		10	20:58		°		'		°		'	Gl version af GeoEel	103	E:\Lomrog07_p	070819C000	690
		48	21:07		°		'		°		'	gun og streamer ude af va				

Cruise: LOMROG 2007			Ship: IB Oden			Location: Arctic Ocean	Page: 3/7			

Line ID	Date d-m-y	SOL/EOL	H:M	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage HDD	Data storage Navigation	Navipac
01E	19-08-2007	4009	21:12	° '	° '	problem med GeoEel igen	104	E:\LOMROG07	070819C000	
		4041		° '	° '	13, 16, 21, 19, 17, 16 m st				791
		4083		° '	° '	13, 12, 14, 18, 18, 18m				
		4164	21:45	87 ° 35,3 '	-4 ° 48 '	19,23,28,30,27,26m strear				
		4268	ca 22:00	° '	° '	fast I isen; russerne komm				
			22:55	° '	° '	russerne igen; styrbord om				
		4275	22:55	87 ° 35.6 '	-5 ° 22.9 '	Fri af isen; 35,50,66,70,70,				
		4292	22:57	° '	° '	19,19,18,19,26,32				
			23:08	° '	° '	fast i isen; russerne komm				
			23:22	° '	° '	Fri af isen- igen				
		4420	23:41	87 ° 36.3 '	-6 ° 09 '	17,18,20,21,22,23				
			23:48	° '	° '	Fast igen				
			00:25	° '	° '	Den russiske redningsman				
			00:29	° '	° '	Sidder fast igen				
			00:52	° '	° '	Befriet igen men Pobedy s				
		4449	00:54	87 ° 36,00 '	-6 ° 21,8 '	og saa sidder vi igen				
			01:29	° '	° '	MEGET taet paa at blive v				
			01:35	° '	° '	Sejler igen				
		4463	01:38	° '	° '	Incomplete dataset.Resett				1213
				° '	° '	Igen fast I isen				
		4464	01:40:22	° '	° '	EOL				1214
2	20-08-2007	4465	13:06	87 ° 35.8 '	-8 ° 35,2 '	SOL	105	E:\LOMROG07	070820C001	1
		4605	13:35	87 ° 37,0 '	-9 ° 01 '	Sidder fast igen. Rus. Paa				141
			13:48	° '	° '	Fri af isen				
			13:49	° '	° '	Fast I isen				
			14:21	° '	° '	Fri af isen				
			14:23	° '	° '	Fast I isen				
		4618	14:49	° '	° '	Fri a. i. Mange stoejspikes				154
		4662	15:00	° '	° '	Fast I isen				198
		4663	15:22	87 ° 37,3 '	-9 ° 15,0 '	Fri igen				199
		4697	15:49	87 ° 38,0 '	-9 ° 16,2 '	Fast I isen				233
		4706	16:14	87 ° 38,1 '	-9 ° 18,0 '	Fri igen				242
		4714	16:18	87 ° 38,2 '	-9 ° 19,2 '	Fast igen				250
		4715	16:24	87 ° 38,2 '	-9 ° 19,2 '	Fri igen ved egen hjaelp ve				251

Cruise: LOMROG 2007	**Ship:** IB Oden	**Location:** Arctic Ocean	**Page:** 4/7

Line ID	Date d-m-y	SOL/EOL	H:M	Start/End Latitude N (°)	Latitude N (′)	Longitude E/W(-) (°)	Longitude E/W(-) (′)	Remarks gun/streamer depths	Data storage LTO-2	HDD	Navigation	Navipac
2	20-08-2007	4773	16:39	87	38,7	-9	33,8	Fast igen	105	E:\LOMROG07	070820C001	311
		4774	16:45	87	38,8	-9	34,9	Fri ved egen hjaelp ved at				312
		4794	16:51	87	39	-9	39	Fast igen, storebror paa ve				332
		4795	17"23	87	39	-9	39	Fri igen, men hvor laenge,				333
								umbilicallen fik en lufttur				c. 375
		4875	17:50	87	39,5	-9	58,8	Fast igen				413
		4876	18:17	87	39,5	-9	58,8	Fri igen				414
		4877	18:19	87	39,4	-9	58,9	Fast igen, mange pressure				415
								Mens Oden venter sejler 5				
		4877	19:27	87	39,2	-9	57,3	Slukker NaviPac og koerer				415
		4878	20:20	87	39,0	-9	56,5	Fri, sejler langt den rende			070820C002	416
		4932	20:35					Fart helt op til 5.6 kn for c.				470
		4968	20:44	87	39,6	-10	24,4	Fast				511
		4969	20:56	87	39,6	-10	24,9	Fri				512
		4995						warning from geometrics, s				
		4996						dis-arm arm				
		5003	21:06					vi sidder fast				550
		5004	21:08					vi sejler igen, 1.3 kn				
		5010						vi sidder fast				
		5011						Russer bakker pa port side				558
		5037	21:29	87	40,1	-10	46,6	3.4 kn				584
		5045						vi sidder fast				
		5046						vi sejler igen				
		5120	22:40					fast og fri igen				
		5171	23:25					Sejler nu umiddelbart bag				
		5213	23:35		41.7	-11	27					762
			23:40					fast I isen (FIS)				
								Streamerdybde41,49,57,64				
	21-08-2007		00:24					Fri af isen (FRIS)				
		5250	00:41									802
		5281	00:54					Ny runline kurs ca 343			070821C000	832
		5326	01:03					Tilbage til gl. Runlinie			070821C001	878
			c 01:10					Streamer paa is. Kommuni				
		5367						Sektion 2-6 tabt. Gevind I e				c. 909

Cruise: LOMROG 2007 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 5/7

Line ID	Date d-m-y	SOL/EOL	H:M	Start/End Latitude N (°)	Latitude N (')	Longitude E/W(-) (°)	Longitude E/W(-) (')	Remarks gun/streamer depths	Data storage LTO-2	HDD	Navigation	Navipac
3	26-08-2007	21	16:00	85	25	-52	23	fejl ved event og file no. sa	106	e:\LOMROG07	070826C000	22
		95	16:20	85	23,7	-52	21,6	Sidder fast i isen				96
		125	17:20	85	23,1	-52	18,6	Fri igen, rus bakkede ned (				126
		149						21///17/17/17/19/20/21				150
		227	17:40		21.8		15.9	16,16,16,19,21,22				228
		230	17:51					vi sejler igen, 1.6 kn				231
		234	17:55					EOL navipac				235
		235	18:01					New navipac runline			070826C001	236
		235						vi sejler igen, og nej				236
		236						nu sejler vi, russer forbi				237
		240						vi sidder fast				241
		241	18:54					vi sejler igen				242
		250						vi sidder fast				251
		251	19:07					vi sejler igen				252
		256	19:08					vi sidder fast				257
		257	19:13					vi sejler igen				258
		270						vi sidder fast				271
		271	19:25	85	21	-52	15,6	vi sejler igen				272
		328	19:40					vi sidder fast				330
		329	19:48					vi sejler igen				331
		333						vi sejler igen				334
		359	20:03					New navipac runline			070826C002	362
		425	20:17					vi sidder fast				427
		426	20:20					vi sejler igen				428
		443						kraftigt sving				448
		460	20:30					Thomas tager helikopter fo				465
		472	20:33					New navipac runline			070826C003	477
		475										480
		521						New navipac runline				525
		522	20:46	85	17,6	-52	03.8				070826C004	526
		597						CNT-2 problemer			070826C005	609
		600	21:06					CNT-2 Ok igen			070826C006	610
		602						vi sidder fast				613
		603						vi sejler igen				614

Cruise: LOMROG 2007 | **Ship:** IB Oden | **Location:** Arctic Ocean | **Page:** 6/7

Line ID	Date d-m-y	SOL/EOL	H:M	Start/End Latitude N				Longitude E/W(-)				Remarks gun/streamer depths	Data storage LTO-2	HDD	Navigation	Navipac
3	26-08-2007	605	21:27	85	°	17,1	'	-51	°	50,1	'	speed ca. 3 kn	106		070826C006	616
		631	21:34		°		'		°		'	russer sidder fast				642
		664	23:10		°		'		°		'	EOL, mistet kontakt til stre				664
03a	27-08-2007	665	00:50		°		'		°		'	SOL indsat 2 nye sektione	107	e:\LOMROG07	070827C000	665
		714	03:52		°		'		°		'	EOL				714
					°		'		°		'					
					°		'		°							
					°		'		°							
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					°		'		°		'					

Cruise: LOMROG 2007			Ship: IB Oden			Location: Arctic Ocean	Page: 7/7			
Line ID	**Date** d-m-y	**SOL/EOL**	**H:M**	**Start/End** Latitude N	Longitude E/W(-)	**Remarks** gun/streamer depths	**Data storage** LTO-2	HDD	Navigation	**Navipac**
4	13-09-2007	1	00:20	76° 17,95'	0° 34,26'	Gun file LOM07E	108	E:\LOMROG07	....C000	1
		2431	07:51	76° 33,9'	-2° 38,9'	Gun SP no. 2434				2433
		2657	08:31	76° 35,6'	-2° 49,9'	Gun SP no. 2661				2660
		3284	10:27	76° 39,8'	-3° 21,0'	Gun SP no. 3291				3287
		3285		° '	° '	Ikke alle events kommer I				
		4875	15:18	76° 49,44'	-4° 43,2'	Maskine 2 ud af 4 startet				4877
		5190		° '	° '	Speed 3 kn				
		5265	16:30	° '	° '	EOL				5267
				° '	° '					
04A	13-09-2007	5268	18:30	76° 51,5'	-5° 03.5'	SOL, Gun SP OK	109	E:\LOMROG07	.....C001	5268
		5517		° '	° '	Speed 2 kn pga isforhold				5520
		5540		° '	° '	Speed 4 kn igen				
		5552	19:29	° '	° '					5555
		5566		° '	° '	lav fart pga is				
		5711		° '	° '	meget stoj paa 25 og op, s				
		5731	20:15	° '	° '	EOL, stort stromforbrug pa				5734
				° '	° '	Sidste sektion kortslutte I t				
				° '	° '					
04B		5737	22:04	76° 53,8'	-5° 23,3'	SOL, Gun file LOM07G	110	E:\LOMROG07	.....C002	5737
		5746	22:??	° '	° '	SKIPPED A SHOT BEFOF				5747
	14-09-2007	6314	00:00	76 57.09 '	-5 54.25 '	midnight sp GUNSP 6315				6315
		6708	01:22	° '	° '	eol				6709
				° '	° '					
				° '	° '					
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Appendix 3: Seismic tape inventory

TAPE INVENTORY LOG

Cruise: LOMROG 07 | **Area:** North of Greenland

Cartridge	Line	Date d - m - y	Regcord length	Sample interval	File/SP range	
100	TEST	15-aug-07	11000	1	1	190
101	01	19-aug-07	11000	1	100	596
102	01A	19-aug-07	11000	1	650	3232
102	01A	19-aug-07	9000	1	3233	3472
103	Per	19-aug-07	9500	1	2	48
104	01E	19-aug-07	9500	1	4000	4464*
105	02	20-aug-07	9500	1	4465	5368
106	03	26-aug-07	8500	1	1	631
107	03A	27-aug-07	8500	1	665	713
108	04	13-sep-07	9500	1	1	5265
109	04A	13-sep-07	9500	1	5268	5731
110	04B	13-sep-07	9500	1	5737	6708

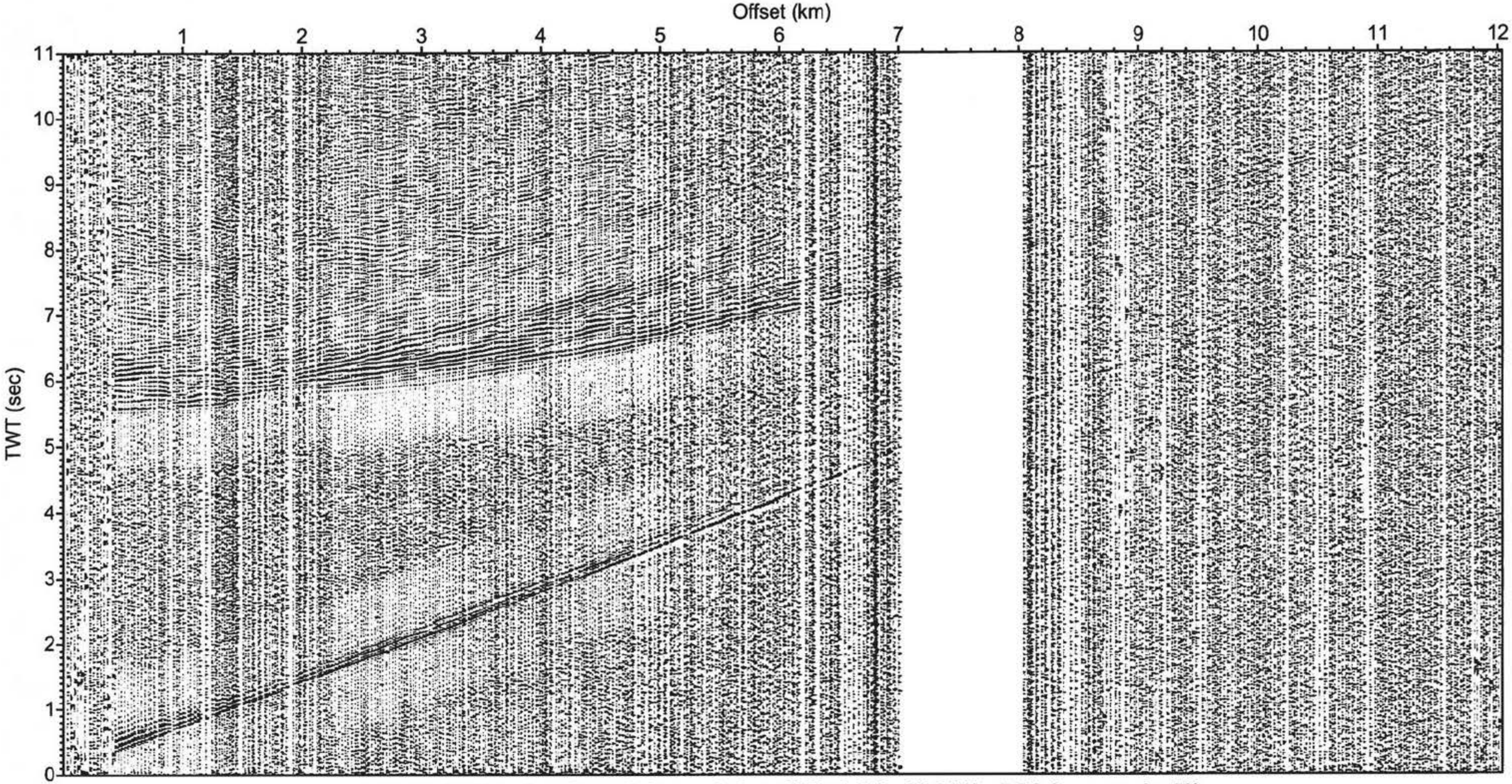
* file 4457-4464 only ch. 49-52

Appendix 4: Sonobuoy appendices

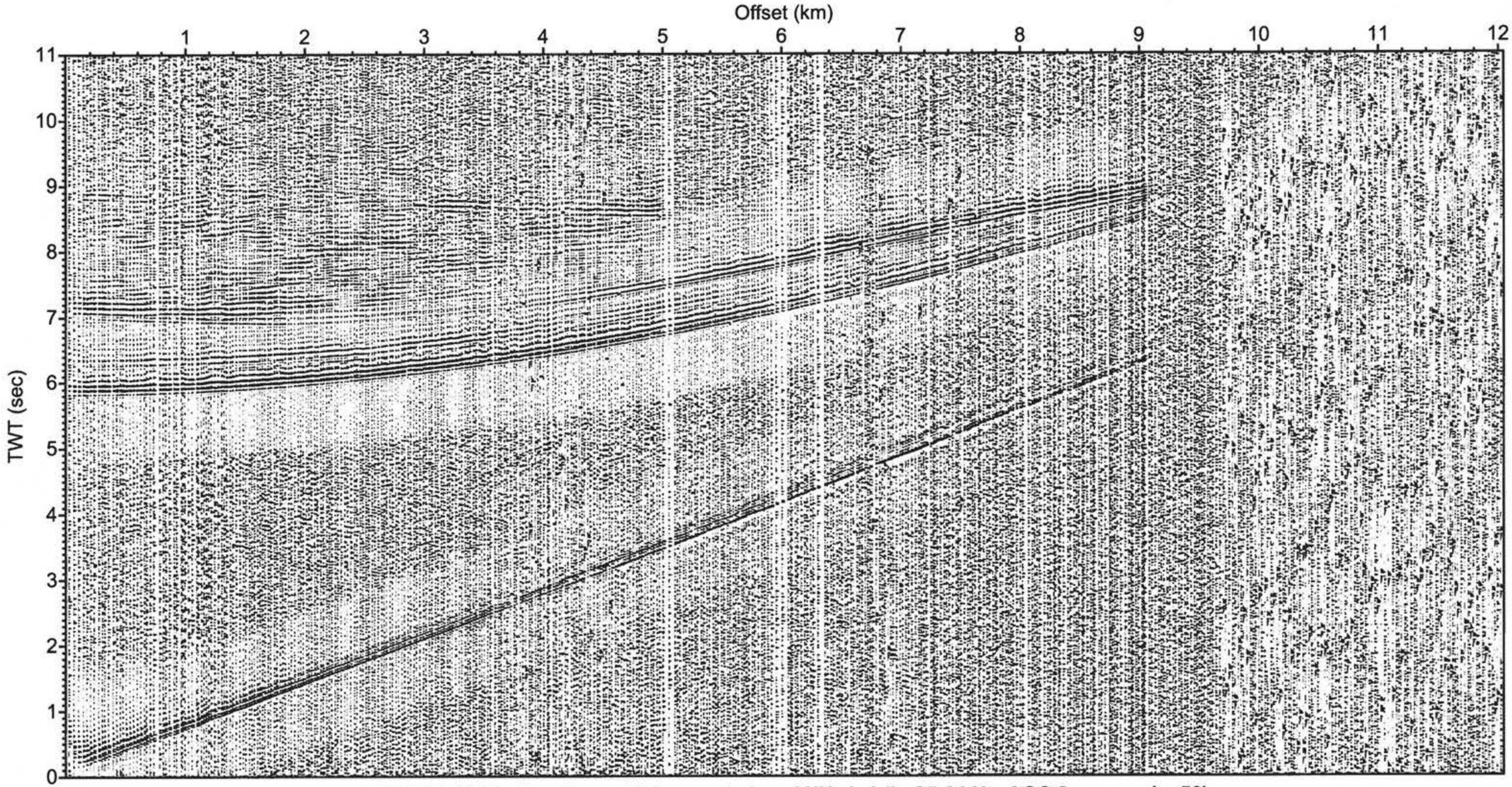
Appendix A

Record sections of all sonobuoys

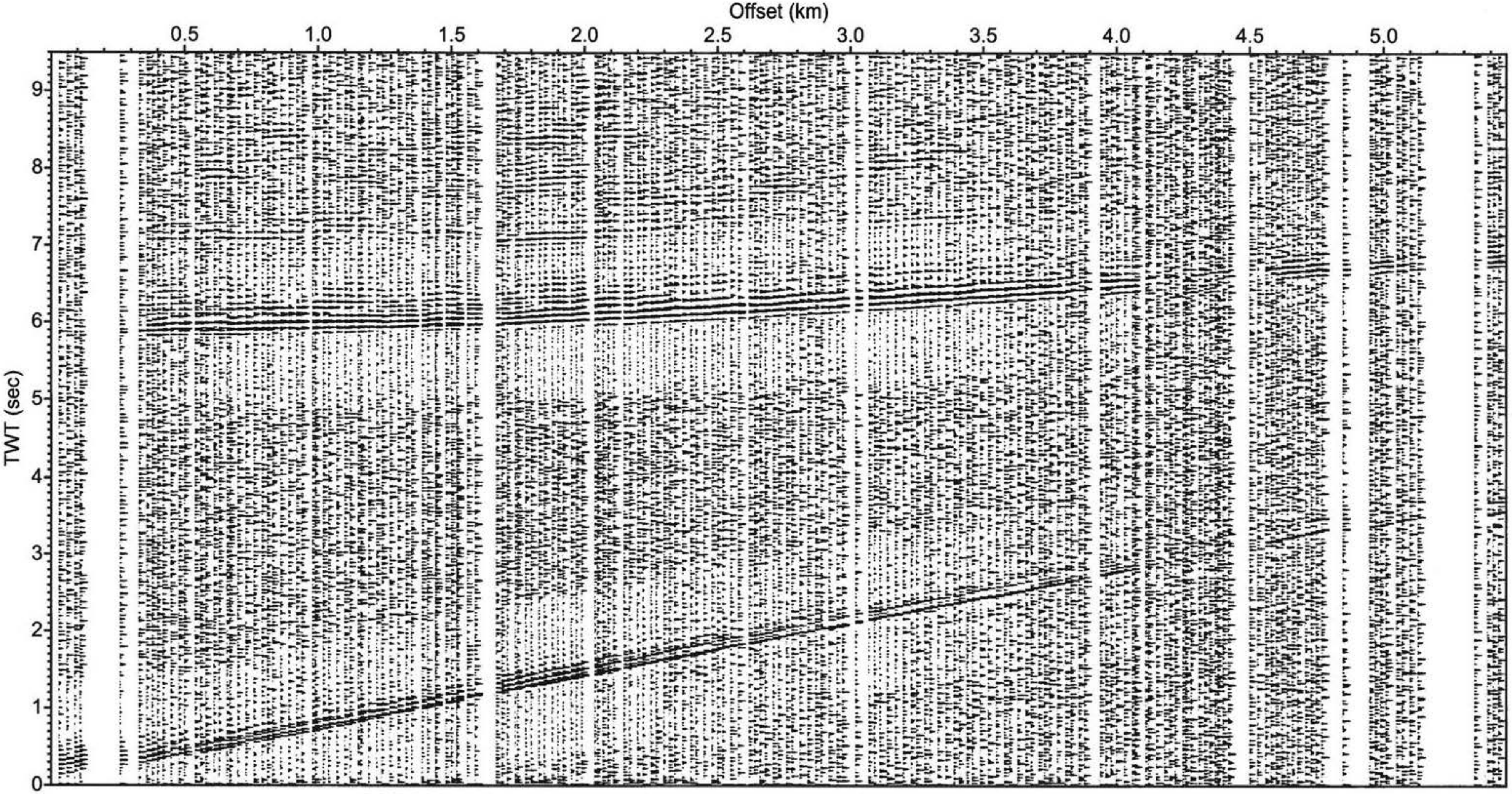
Shot-receiver offsets (horizontal scale) in the record sections are corrected for the drift of the sonobuoys. Vertical scale is the traveltime displayed. For sonobuoys on line 4, the traveltime is reduced with a reduction velocity of 4.5 km/s.



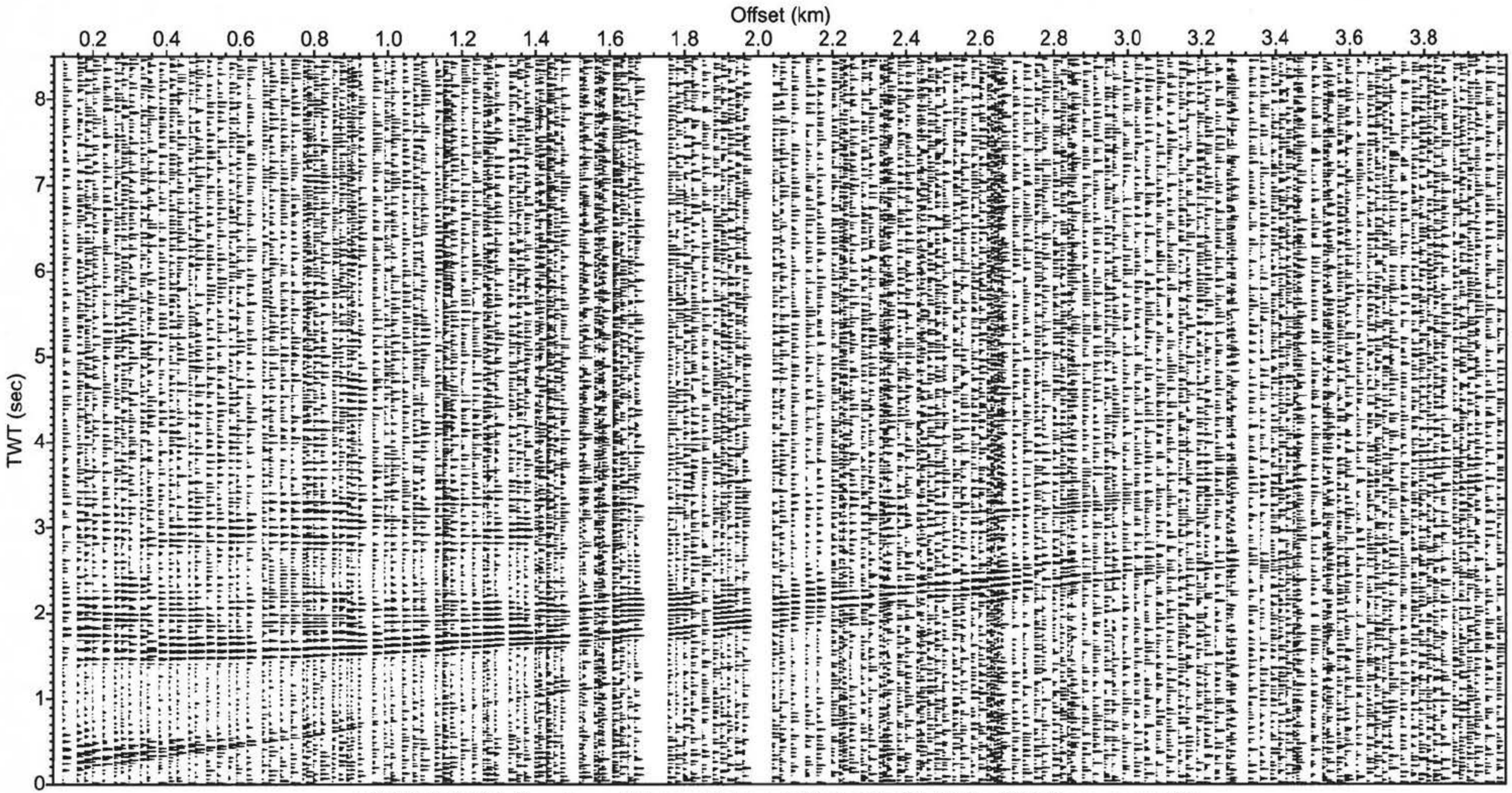
LOMROG 2007 - Sonobuoy 1-1 recorded on AUX ch 1 (bpf 5-24 Hz, AGC 2 sec, scale=50)



LOMROG 2007 - Sonobuoy 1A-2 recorded on AUX ch 1 (bpf 5-24 Hz, AGC 2 sec, scale=50)



LOMROG 2007 - Sonobuoy 1E-5 recorded on AUX ch 1 (bpf 5-24 Hz, AGC 2 sec, scale=50)



LOMROG 2007 - Sonobuoy 3-7 recorded on AUX ch 1 (bpf 5-24 Hz, AGC 2 sec, scale=50)

Appendix B

Technical specifications VHF antenna MD G3

MOONRAKER

Type MD-G3

High Gain Broadband Collinear
for marine or land VHF Marine Band communications

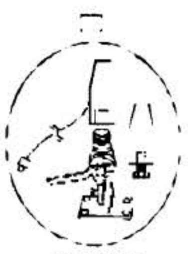
A rugged lightweight 5/8 wave ground independent collinear to give efficient and dependable performance.

The type MD-G3 has been designed as a robust, high gain antenna system and is ideally suited for base station and marine mobile use. It is constructed of marine grade, low corrosion, tempered aluminium alloy tubing which is completely coated with black (option of white) PVC to provide maximum protection from harsh environments and ultra-violet radiation. all metal parts are at DC earth potential for static discharge and fittings are of nylon and chromed bronze.

Mounting is easily effected by way of nylon side mount insulators,(or by straps or clamps to mast or tower section), by 12mm metric base bolt or by a heavy duty stainless steel swingdown mount adjustable in two planes.

Specifications

VHF Band	**150-170 MHz**
Overall Length	2.78 metres (9.12 ft)
Base Section Diameter	22.24 (7/8 in)
Top Section Diameter	10 mm (0.4 in)
Pattern	Omnidirectional
Polarisation	Vertical
Frequency Range	Standard Version: full marine band 156-162 MHz
Bandwidth	7 MHz at <1.5:1 VSWR; 20 MHz at <2:1 VSWR
Gain	5 dBi
Impedance	50Ω nominal
Wind Loading	2.35 kg at 100 km/h (5.2 lbs at 60 mph) 3.56 kg at 120 km/h (7.8 lbs at 75 mph)
Power Capability	75 watts
Mountings	Either two 63 mm (2.5 in) nylon clamp type insulators, 35 mm diameter (1 3/8 in), threaded to take M10 set screw, or heavy duty galvanised hose clamps (recommended spacing not less than 25 cm (9.8 in) apart); stainless steel swingdown mount (1" thread) adjustable in both planes (not supplied); or base mounted 12mm metric bolt (not supplied).
Connection	5 metres RG58 coaxial cable with PL259 (UHF) connector; or female N Type connector permanently fitted in base of mounting tube (sidemount type)
Packed Weight	3 kg (6.6 lbs)



Mounting options

Specifications subject to change 5/04

Moonraker Australia Pty. Ltd. A.B.N. 57 009 531 211
Tasmania Technopark, Dowsing Point 7010, Tasmania Australia
Website: www.moonraker.com.au Telephone 61 (0)3 6273 1533 Fax: 61 (0)3 6273 1749 Email: radiocom@moonraker.com.au

Appendix C

Technical specifications sonobuoy receiver WR-2902e

WR-2902e

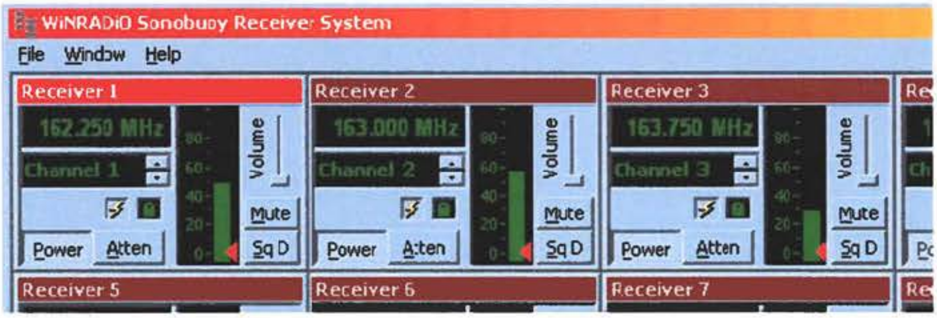
The WiNRADiO WR-2902e VHF/UHF Sonobuoy Telemetry Receiver is designed to receive signals from analogue (DIFAR) and digital (BARRA) sonobuoy transmitters, operating in the 136 to 173.5 MHz frequency range. This standard frequency range can be easily extended up to 1.5 GHz to suit special requirements.

The WR-2902e is a triple conversion superheterodyne receiver. It features a single antenna input, separate analog and digital signal outputs, and an audio output for monitoring.

The receiver is enclosed in a ruggedized aluminium enclosure and can be connected to any standard computer either via a serial port, or (optionally) via USB or PCMCIA ports. As all RF signal processing is performed by the receiver, the computer hardware and software requirements are modest and a standard laptop can be used to control the receiver. More than one receiver can be connected to a single computer, the number depending only on the availability of ports.

The WR-2902e receiver is supplied with Windows based application software and a DLL library developed for easy system integration into custom designed sonobuoy systems.

The Windows application software shows a graphical representation of all installed receivers (a virtual control panel), making it possible to observe the status of all receivers at a glance and make individual adjustments if necessary. Each receiver can be monitored, and a mixing facility is provided where a particular receiver can be selected for audio monitoring by simply clicking on the corresponding receiver panel.



WR-2902e Control Panel (a portion only shown)

Technical Specifications

Frequency range	136.000-173.500 MHz
Channel spacing	375 kHz
Modes	Analogue FM (DIFAR), High speed digital (BARRA)
Sensitivity	0.9 µV (DIFAR), 1.5uV (BARRA)
IF bandwidth	230kHz @ -6dB

Skirt selectivity	470kHz @ -25dB 730kHz @ -60dB
Frequency response	Less than ± 1 dB variation from 5 Hz to 25 kHz (analog) 5Hz to 150kHz (digital)
Output level	1.0 ± 0.1V rms @ 75kHz devn. and 1kHz mod. frequency (DIFAR), TTL compatible (BARRA)
RSSI range	Exceeds 60dB for 5dB linearity
Image rejection	80 dB or better
Frequency stability	±20 ppm or better
Input impedance	50 ohm (nominal)
Connectors	RF input (BNC), DIFAR output (SMA), BARRA output (SMA); 3.5mm audio jack for monitoring
Power requirements	+12V @ 420 mA
Total power consumption	5 W max
Dimensions	216 x 121 x 45 mm (8.5" x 4.75" x 1.75")
Mass	1350 g (47.25 oz)
Ambient temperature	Storage: -20° to +75° C Operation: 0° to +45° C

(Specifications are subject to change without notice.)

Appendix D

Technical specifications Taurus seismometer from Nanometrics

(ACTUAL SIZE)

Taurus Technical Specifications

Sensor inputs

Channels	3 standard, field upgradeable to 6 or 9 with addition of external Trident digitisers
Sampling	Simultaneous
Input voltage range	40 V peak-to-peak differential (at gain = 0.4)
Nominal sensitivity	1 count/μV (gain = 1)
Hardware gain selection	Software configurable 0.4, 1, 2, 4, 8
Software gain	User configurable 0.001 to 100
High pass filter	User configurable in mHz

Digitiser performance

Type	Proprietary high order sigma-delta
Digital filter	140 dB attenuation at output Nyquist
Filter type	Linear phase (consult factory for other options)
Dynamic range	> 138 dB @ 100 sps (max sine wave above shorted input)
Sample rates	10, 20, 40, 50, 80, 100, 120, 200, 250, 500 sps

Sensor support

Sensor types	Broadband active and short period passive
Control lines	3; typically used for Cal enable, mass center and mass lock/unlock Logic level configurable: High: 5 V, 12 V, open drain. Low: 0 V, open drain
Sensor power	Supply power pass-through to sensor (9-36 VDC). Protected against short circuit. Sensor power can be switched on/off from user interface.
Auto mass centering	Configurable mass position threshold with autocentering or centering scheduled with configurable repeat interval. In autocentering mode, mass centering will be repeated until masses are within limits.
Sensor management	Supports digital interface to Nanometrics Trillium 120 seismometer

Calibration output

Calibration signal	Ramped sine wave, configurable frequency and amplitude Pseudo-random binary
Calibration initiation	User interface (local or remote)
Calibration mode	Voltage or current

Timing

Timing system	Internal DCXO clock disciplined to GPS
GPS receiver	Internal 8 channel receiver
GPS antenna	External active antenna supplied with 5 meter cable
Duty cycle	Software configurable

Instrument state-of-health

Taurus records continuous instrument state-of-health including:

	Power supply voltage Seismometer mass position Calibration enabled bit for each channel GPS state-of-health Instrument temperature Signal clip indication bit
User accessible SOH	4 external SOH channels (12-bit)
Configuration	Complete configuration audit trail
Communications	Complete audit trail with cumulative good/bad packet counts
Log file	All software generated log messages are stored with the data

Internal data storage

Standard	Single, 1.8" ATA disk drive slot Single, Type I/II Compact Flash slot Both storage options are removable. Storage media are accessed via the media door on the end of the unit.

The following media options are available:

Compact Flash	Standard and industrial grade Type I/II. 1 or 2 Gbyte; Contact factory for larger capacity options.
1.8" ATA disk drive	10 or 30 Gbyte
Duration	> 600 days continuous recording, 3-channels @ 100 sps on 30 GByte ATA drive (~ 40 days on 2 Gbyte Compact Flash)
Recording modes	Continuous, write once or ringbuffer (overwrites oldest data) Continuous with STA/LTA trigger flags
File system	FAT32
Storage format	Nanometrics Store. Direct data output in MiniSEED and Nanometrics formats.

Data retrieval

Media exchange	Compact Flash and ATA drives are field swappable
Download interfaces	10/100 Base-T Ethernet

Real-time data communications

Interfaces	10/100 Base-T Ethernet, RS-232 serial
Protocols	UDP/IP unicast/multicast HTTP (POST and GET) RS-232 serial with IP drivers

Integrated user interface

LCD display	240 * 320 colour graphics display with backlight
Interface	Web browser with five button navigation
LED	System status tri-colour LED, Ethernet communications LED, Media status LED

Configuration

Taurus is configurable locally via the colour LCD display and onboard browser or remote using any web browser connected to the unit. Multiple unit configuration is achieved using an optional group configuration web server. Consult factory for further informati

Software

Operating system	Linux
Applications software	Nanometrics next generation NAQS Server with web interface

Connectors

Sensor connector	26-pin mil circular. Primary data channels, sensor control lines, protected/switchable sensor power, digital serial sensor management interface
Serial/USB	19-pin mil circular Serial port 1: Rx, Tx, RTS, CTS, DTR, DSR, CD, RI Serial port 2: Rx, Tx, RTS, CTS (data collection from serial devices) USB master: Data, Pwr (5 V, 100 mA) Serial device power (pass through supply voltage)
GPS	TNC, active antenna connection (3.3 V)
Ethernet	4-pin mil circular, 10/100 Base-T
User SOH	7-pin mil circular, 4 analog SOH inputs, SOH ref., 3.3 V @ 10 mA pow
NMXBus	4-pin mil circular, NMXbus data and power
Power	3-pin mil circular, 9-36 VDC
USB	USB master/slave accessible behind media door

Power

Power system	Protected fuseless design with configurable low power disconnect reverse protection and short circuit protection
Ultra-low power mode	650 mW @ 12 Volts, 3-channel continuous recording @ 100 sps < 100 μsec timing precision, Compact Flash recording
Low power	1.1 Watt @ 12 Volts, 3-channel continuous recording @ 100 sps, continuous serial data acquisition (external geodetic GPS or equivalent), < 100 μsec timing precision, internal disk or Compa Flash recording
Communications mode	1.5 Watt typical; 3-channel continuous recording @ 100 sps, < 1 μsec timing precision, real-time Ethernet or serial communicatio
Configuration	< 3.5 Watts. All systems operational including colour graphics displ
Low voltage disconnect	Software configurable

Environmental

Operating temp.	-20°C to +60°C base unit using Compact Flash storage +5°C to +55°C base unit using 1.8" ATA disk storage
Storage temp.	-40°C to +70°C
Humidity	100%
Length	264 mm
Width	147 mm
Depth	60 mm
Weight	1.8 Kg

Nanometrics
SEISMOLOGICAL INSTRUMENTS

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Appendix E

Technical specifications sonobuoy AN/SSQ-53D(2) from ULTRA Electronics

AN/SSQ–53D(2)
Directional Passive Sonobuoy

Search, localization and tracking of sub-surface and surface targets of interest

The Hermes' AN/SSQ-53D(2) DIFAR sonobuoy offers outstanding detection performance at frequencies from 5 to 2400 Hz. It's directional capability permits ASW forces to detect and track a contact with a single DIFAR and to fix it's position with as few as two DIFARs. The Hermes designed AN/SSQ-53D(2) has set new standards for sonic performance and reliability through the incorporation of a state-of-the-art hydrophone coupled with a complementary suspension system. The result is the world's only fully qualified ambient noise limited DIFAR sonobuoy.

- "A" size micro-processor controlled passive directional sonobuoy
- Extremely low sonobuoy self-noise
- Electronic Function Select (EFS) permits operator pre-deployment selection of:
  - One of 99 VHF transmit channels
  - Five operating periods
  - Three selectable hydrophone depths
- Exceptional low-frequency capability
- Compatible with all known acoustic processors
- Proven reliability
- Competitively priced with lesser capable directional and non-directional sonobuoys

Engineered for reliable performance using leading-edge technology

Ultra
ELECTRONICS

SPECIFICATIONS

GENERAL DESCRIPTION

Description	*DIFAR, passive, directional*
Function	*Search, localization, surveillance*
Applicable Specification	*Production sonobuoy specification dated 26 Oct 94 as modified by the Canadian Forces*
Dimensions	*36.00 in (914 mm) long by 4.875 in (124 mm) diameter*
Weight	*16.5 lbs (7.5 kg)*
Power Source	*Seawater activated battery (main power source)* *Lithium battery (EFS display and memory)*
Stabilization Time (after splash)	*Up to 100 seconds (shallow)* *160 seconds (medium)* *240 seconds (deep)*
Operating Life	*0.5, 1, 2, 4 or 8 hours preselectable*
Scuttling Time	*At 8 hours, regardless of operating life*
NATO Stock Number	*5845-21-909-8480*

TRANSMITTER CHARACTERISTICS

Frequency Range	136 MHz to 173.5 MHz
Transmission Channels	*99 preselectable, with EFS display*
Transmitter RF Power	*1 W minimum*

SENSOR CHARACTERISTICS

Acoustic Frequency Range	*5-2400 Hz*
Sensitivity, Directional	*122 ± 3 dB rel 1 μPa at 100 Hz = 40kHz pk dev*
Sensitivity, Omnidirectional	*122 ± 3 dB rel 1 μPa at 100 Hz = 25 kHz pk dev*
Operating Depth	*30 metres, 120 metres, and 300 metres preselectable*
Decent time (in water)	*40 seconds (shallow)* *100 seconds (medium)* *180 seconds (deep)*
Directivity, Directional	*Horizontal cosine ± 1 dB* *Vertical cosine ± 3 dB*
Directivity, Omnidirectional	*± 1 dB horizontal* *± 3 dB vertical*

OPERATING ENVIRONMENTAL CONDITIONS

Launch Temperature	*-20°C to +55°C*
Seawater Temperature	*0°C to 35°C*
Wind Velocity	*30 knots (maximum)*
Sea State	*6 (maximum)*
Maximum Launch Altitude	*30,000 ft (9144 m)*
Maximum Launch Airspeed	*370 knots IAS at 1850 ft (564 m)*

Ultra ELECTRONICS

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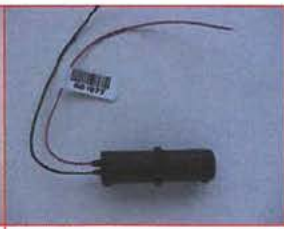
08/99/AN/SSQ-53D(2)
Printed in Canada, 1999

Appendix F

Technical specifications hydrophone Teledyne/Benthos AQ-2000

Hydrophones

HYDROPHONE ELEMENTS

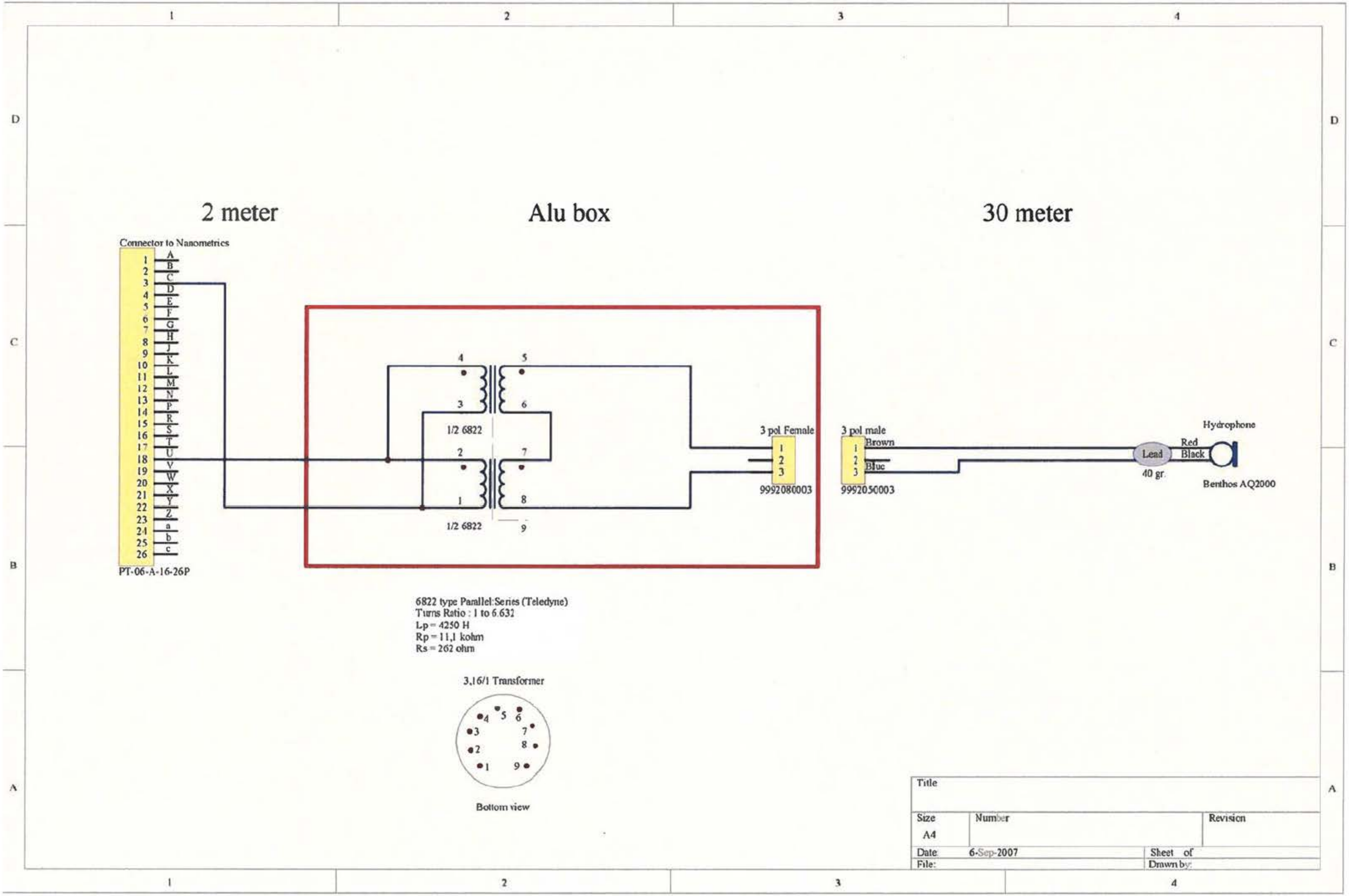



SPECIFICATIONS	Geopoint	Geopoint Export	AQ-2000	AQ-1
Suggested application	Seismic arrays	Seismic arrays, meets export restrictions	Seismic arrays, ocean bottom cables, general purpose	Seismic arrays, ocean bottom cables, general purpose
Sensitivity (dBv re 1 uPa @ 20 C)	-194	-194	-201	-201
Sensitivity (V/Bar @ 20 C)	20	20	8.9	8.9
Capacitance (nF @ 20 C)	16	16	4.5	14.5
Frequency Response (+/- 1.5 dB)	1 Hz to 1 kHz	1 Hz to 500 Hz	1 Hz to 10 kHz	1 Hz to 10 kHz
Depth (meters)	200	200 (Cutoff at 35 m maximum)	2000	1732
Length (cm)	5.1	6.5	4.6	4.5
Diameter (cm)	1.7	2.3	1.65	1.6
Weight (g)	25.0	33.0	14.0	17.3
Leads	Two AWG 26	Two AWG 26	Two AWG 28	Solder pins

TELEDYNE BENTHOS
A Teledyne Technologies Company

Appendix G

Technical drawing of the hydrophone connection to the Taurus recorder



2 meter
Alu box
30 meter
Connector to Nanometrics
PT-06-A-16-26P
1/2 6822
1/2 6822
3 pol Female
9992080003
3 pol male
9992050003
Brown
Blue
Lead
40 gr.
Red
Black
Hydrophone
Benthos AQ2000
6822 type Parallel:Series (Teledyne)
Turns Ratio : 1 to 6.632
Lp = 4250 H
Rp = 11,1 kohm
Rs = 262 ohm
3,16/1 Transformer
Bottom view
Title
Size
A4
Number
Revision
Date
6-Sep-2007
Sheet of
File:
Drawn by:

Appendix H

Technical specifications Mark Products L4 1-Hz vertical geophone

L-4

High Sensitivity Seismometer

1.0 Hz and 2.0 Hz Land or Borehole Seismometer

Features

- Stable Natural Frequency
- Lowest Distortion
- Instrument Quality
- Humbuck Construction
- Very High Output
- No Spring Sag
- Shallow surface hole, borehole and horizontal versions

The L-4 is an INSTRUMENT QUALITY 1 Hz or 2 Hz multi-purpose seismometer that is small, light, and economical. It is designed specifically for scientific studies, yet has the ruggedness required for petroleum exploration work.

L-4 design ELIMINATES the usual causes of failure in VERY LOW FREQUENCY geophones, such as SPRING FATIGUE, OVER-STRESS and INSTABILITY. This seismometer maintains a close frequency tolerance with tilt and temperature and is TRANSPORTED WITHOUT CLAMPING the moving element.

L-4 is available with or without calibration coils and may be obtained as VERTICAL OR HORIZONTAL elements. A variety of fittings are available for custom application.

Specifications

	L-4C 1.0 Hz SEISMOMETER	L-4A 2.0 Hz SEISMOMETER
Type	Moving dual coil, humbuck wound	Moving dual coil, humbuck wound
Frequency	1.0 ± 0.05 Hz measured on 200 pound weight at 0.09 inches/second	2.0 ± 0.25 Hz measured on 200 pound weight at 0.09 inches/second
Frequency change with tilt	Less than 0.05 Hz at 5° from vertical	Less than 0.10 Hz at 10° from vertical
Frequency change with excitation	Less than 0.05 Hz from 0 to 0.09 inches/second	Less than 0.10 Hz from 0 to 0.18 inches/second
Suspended mass	1000 g	500 g
Standard coil resistances	500, 2000, 5500	500, 2000, 5500
Leakage to case	100 megohm minimum at 500 V	100 megohm minimum at 500 V
Transduction power	$0.0948 \sqrt{Rc}$	$0.0948 \sqrt{Rc}$
Open circuit damping	(bo) = 0.28 critical	(bo) = 0.28 critical
Coil current damping	$(bc) = \frac{1.1\ Rc}{Rs + Rc}$	$(bc) = \frac{1.1\ Rc}{Rs + Rc}$
Coil inductance	Lc = 0.0011 Rc (henries)	Lc = 0.0011 Rc (henries)
Case to coil motion	0.250 inches peak-to-peak	0.250 inches peak-to-peak
Electric analog	$C_c = \frac{73{,}500}{Rc}$ (microfarads)	$C_c = \frac{36{,}500}{Rc}$ (microfarads)
Electric analog of inductance	Lm = 0.345 Rc (henries)	Lm = 0.17 Rc (henries)
Case height	13 cm ($5^{1/8}$ inches)	13 cm ($5^{1/8}$ inches)
Case diameter	7.6 cm (3 inches)	7.6 cm (3 inches)
Total density	3.7 g/cm^3	2.9 g/cm^3
Total weight	2.15 kg ($4^{3/4}$ pounds)	1.7 kg ($3^{3/4}$ pounds)
Operating temperature Range :	-29° to 60°C (- 20° to 140°F)	-29° to 60°C (- 20° to 140°F)

COIL RESISTANCE, OHMS	500	2000	5500	500	2000	5500
Transduction, Volts/in/sec	2.12	4.23	7.03	2.12	4.23	7.03
Coil inductance, henries	0.55	2.20	6.05	0.55	2.20	6.05
Analog capacitance, microfarads	147	36.8	13.4	73.0	18.3	6.64
Analog inductance, henries	173	690	1900	85.0	340	935
Shunt for 0.70 damping, ohm	810	3238	8905	810	3238	8905